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DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Summer Meeting of the Institution of Mechanical Engineers

A NUMBER of the papers given at Cambridge on the occasion of the summer meeting of the Institution of Mechanical Engineers are of direct interest to chemical engineers.

A few issues ago this journal published a short article on method of flow measurement by means of an aerofoil. One of the advantages claimed for this particular method of measurement flow was that it was unaffected by surface roughness of the pipe or ducting in which it was fitted. This point receives indirect emphasis from one of the papers given at Cambridge. The paper by Dr. W. J. Clark and R. C. Stephens "The Effect of Pipe Roughness on Flow Measurement by Square-edged Orifice Plates" discusses the effect of different kinds of roughness at various parts of an orifice plate installation. The roughnesses in the experimental work described in this paper were produced by lining sections of pipe with closely packed peas or glass beads, with sand, with wallpaper, and by other methods. The results showed that while the effect of roughness downstream was negligible, that upstream had a considerable influence upon the performance of the orifice. With a ratio of orifice to pipe diameter of approximately 0.7 and using glass spheres about $\frac{1}{4}$ in. diameter as the roughness source a 30% reduction in discharge coefficient, compared with that obtained with a smooth pipe upstream, was obtained.

In an actual installation where roughness has developed during use, the extent of the errors involved can be estimated very approximately once the surface roughness has been examined. Where dirty fluids are to be handled the authors concluded that it is better to design the installation with a readily detachable upstream section. This enables a clean section to be fitted whilst the dirty one is being cleaned. A useful suggestion made by the authors is to fit a connection in the upstream section of the pipeline so that its surface condition can be inspected from time to time by means of an introscope.

New Light on Bolted Flanged Joints

Another paper by Professor M. B. Donald and one of the contributors to *British Chemical Engineering*, Dr. J. M. Salomon, dealing with the behaviour of the compressed-asbestos-fibre gaskets in narrow-faced bolted flanged joints, contributes to an understanding of the conditions necessary for maintaining tightness of flanged bolted joints. The authors are of the opinion that the A.S.M.E. Code for Unfired Pressure Vessels is incorrect in assuming "gasket factors" to be independent of gasket width and to decrease with increasing gasket thickness for their work showed that gasket factors increase with thickness and decrease with width.

The A.S.M.E. Code referred to assumes also that the minimum pressure which must be imposed upon a gasket to make a joint increases with decreasing gasket thickness. Their experiments, however, demonstrated (with water as the pressure fluid) that the seating pressure is independent of gasket dimensions.

The authors indicate moreover that increase in gasket thickness and decrease in its width are accompanied by a decrease in the pressure which a joint is capable of containing.

Unsteady-state Heat-transfer Coefficients

Unsteady-State Heat Transfer to and from Gases in Laminar Flow was the subject of a paper given by Dr. T. D. Patten. Problems in unsteady-state heat transfer occur very frequently in modern industrial practice. Nevertheless, very little has been published on the determination of heat transfer coefficients in the unsteady-state. Consequently this paper is a welcome contribution to the subject. The heat transfer coefficients obtained experimentally were shown to be of the same order as those predicted by the theories of steady-state heat transfer for either cooling or heating.

In a regenerative exchanger if the tube wall temperature is nearly uniform and if cooling and heating of the wall are not taking place simultaneously the actual heat transfer coefficients were found to be greater than those predicted for steady-state conditions. This was considered to be due to increase in the heat-transfer coefficient at the entry length of the exchanger.

Alkali Inspectors Report for 1956

THIS Annual Report abounds with useful information on the operation and performance of various nuisance abating devices which have necessarily to be employed at chemical works; it contains also useful advice on avenues of research which might be profitably explored, to improve such appliances and reduce emissions constituting a nuisance.

The report gives a great deal of attention to mist formation occurrence and notes that these are much more widespread now than in the pre-war years. Means of treatment are costly, consequently a good line of attack is to deal with such troubles at source. Activity in this direction, however, requires a great deal of reliable and fundamental research; that the D.S.I.R. are actively interested in this direction is a hopeful sign.

Among the industries mentioned as nuisance-prone is the cement industry where the problem is more acute today than before the war because the output of cement has doubled since those times.

In cement manufacture the main problem of dedusting concerns the kiln gases—as much as 200,000 cu. ft. of gases are emitted per ton of cement clinker produced. Sometimes the dust burden of the kiln effluent gases is worsened by the heat recovery devices used outside the kiln or within it. In the latter case, for example, the chain system, although contributing to thermal efficiency, can

at the same time increase the dust output. Of the dedusting systems available probably the best is the electrostatic precipitator. But many problems attend their installation, especially when they are added to existing plants more or less as the result of additional thoughts on design. One of the outstanding difficulties apart from the size and therefore the cost of such units is the moisture content of the gases to be treated. This brings with it the hazard of condensation and the possibility of serious corrosion of the electrical equipment. With new plants the precipitation equipment can be erected close to the kiln and the danger of condensation thereby minimised. But with older plants where the design did not originally cater for electrostatic precipitators their installation inevitably involves long connections from kiln to precipitator. In such plants corrosion is difficult to avoid even where lagging and jacketing for the purpose of heating by warm gases is practised. Incidentally, whatever measures are used successfully to reduce dust emission the characteristic white plume from the chimney stacks of cement works would always be in evidence, for these appearances do not indicate dust emission.

Sulphuric Acid Mists

Sulphuric acids works are also the subject of comment in this connection but before the report proceeds to deal with such works some interesting facts of the state of the industry are given. For example, the output of acid produced through processes using oxides of nitrogen is 21.6% of the total monohydrate produced in the country. The balance is produced *via* the contact process. Despite this the older process still manufactures something like 4 to 5 thousand tons of acid per year.

Two experiences of tower plants whose escaping gases were satisfactory as regards their acid content but whose mistiness gave rise to local complaints are described. Various methods of demisting at the time the report was written were to be tried to alleviate the nuisance. Included among them was the use of ceramic filters.

Chamber-acid Plants

For arresting acid droplets from chamber-acid plants the report reveals that 90% of the entrainment can be trapped by simple impact arrestor of the multiple venetian blind type. They have the additional advantage of causing only a very low pressure drop of the order of one quarter of an inch water gauge. The smaller droplets which may escape from chamber acid plants are in the micron size range. Another remedy which is being actively pursued is to prevent droplet formation at source. For this purpose non-splash acid distributors are being tried on the Gay-Lussac tower of one plant above which are to be fitted a few inches of "dry" packing.

In dealing with contact plants the report states that the general custom to minimize acid emission is to rely upon a high degree of conversion followed by efficient SO_3 absorption. Nuisances at plants employing elemental sulphur as the source of SO_3 arose in one case from leaking heat exchangers and in another through a faulty pyrometer at the burner. At yet another plant where mist trouble occurred all the known remedies with the exception of electrostatic precipitators were tried without success. It will be interesting to see whether by the time the next Alkali Inspectors Report is issued mist emission will have been diminished at this plant without the use of electro precipitators.

A nuisance was caused at a pyrites burning plant through insufficient feed of pyrites to the roasters. This particular plant was converted subsequently to sulphur burning but an electrically heated pre-heater requested by the Inspectorate when installed was found to have been designed under capacity.

At anhydrite plants the main difficulty seems to have been the emission of mist. Ceramic filters were tried unsuccessfully in one case for waste gas treatment and there seems little possibility of solving the problem in this particular case without the use of electro precipitators. At another plant where attempts to remove mist were made with water scrubbers a decision has already been taken to install them.

Father of the Nuclear Programme

BY the death of Lord Cherwell on July 3, Britain lost a distinguished elder statesman in science, and the man who fathered the British Atomic Energy project through the critical period when it ceased to be purely of defence interest. He did more than any other single person to bring the U.K. Atomic Energy Authority into existence, and it was as Paymaster General and chairman of the Atomic Energy Council that he obtained the approval of the government to proceed with the experiment of using an extension of the nuclear weapons programme to build reactors which could be forerunners of those for use in civil power development. Essentially an academic scientist, he showed, nevertheless, great practical commonsense and acumen and did much to promote the application of science to the country's economy. After the outbreak of the Second World War when Mr. Churchill took office, Frederick Lindemann, F.R.S., as he was then, was given the post of the Prime Minister's personal assistant and he retained this to the end of the war. He was not solely concerned with advice on difficult scientific problems but he served as a man of independent judgment and wide experience of the French and German mentality, and whose views on problems involving numbers and quantities of any kind were unbiased and useful. In 1941 he was created Baron Cherwell and the following year sworn of the Privy Council as Paymaster General, an office he held until 1945. He was one of the first to realise that nuclear weapons could win or lose a war, and he was the leading British spokesman for the small band of scientists who guessed what might be possible with nuclear weapons and who feared that the enemy nations might use them to win the war. The urgency of that fear caused the United States' President and Mr. Churchill to set up the Manhattan District. Between 1951 and 1953 Lord Cherwell was again Mr. Churchill's adviser on atomic energy research and development and on scientific and statistical matters generally. He resigned his Cabinet post in October, 1953 because his leave of absence from his academic duties at Oxford, where he was Professor of Experimental Philosophy, had expired. He was made C.H. that year and, in 1956, a viscount.

Controversy Over Stress-Relief

THE question of when stress-relieving is necessary is one of those "rare scientific problems" which remain controversial for a long time, said Dr. R. Weck, Cambridge University Lecturer in Engineering, when he introduced his paper on views on stress relief at the Institute of Welding's Commonwealth Conference in London, recently. The problem, he continued, touched on the "innermost beliefs of people" and it was difficult to discuss dispassionately. Some of the nine processes used for stress relief also had

other effects and it was these, he suggested, which, deliberately or inadvertently, were the reasons for their use. Thus heat treatment of a mild-steel structure in a furnace at 600-650°C not only relieves completely the residual stresses but improves the ductility of the metal, it results in degasification of the weld metal and eliminates undesirable consequences of previous cold work, such as work hardening and strain ageing. It will soften the heat-affected zones, and will dissolve carbide precipitates in the grain boundaries. The same process might have adverse secondary effects, too, but it had never been seriously suggested that these outweighed the beneficial ones. During the past ten years a prodigious research effort in Great Britain and elsewhere had resulted in evidence that would permit the problem to be resolved unequivocally if it were examined objectively. Much of the evidence, particularly in regard to brittle fracture, is rejected because it is based on laboratory tests, which are necessarily on a smaller scale and under simpler conditions than those that may be said to apply (in the absence of evidence to the contrary) in the full-scale structure. There were signs, however, that experimental evidence is now accumulating at such a rate, and is becoming so overwhelming that even the most sceptical, Dr. Weck declared, will have to withdraw from positions that are gradually becoming untenable. Dr. Weck is working on a broad international inquiry in order to assess the views on different fairly clearly specified points concerning this important group of problems, and he assured the Conference that the co-operation that he has received, in this country and abroad, has been "very enthusiastic indeed."

Severn-side Chemical Plant

CHEMICAL plant worth £100 million for manufacturing organic and inorganic products largely from oil will be erected by I.C.I. during the next 20 years at a site in Thornbury, Gloucestershire, if the company is granted the permission for development that it is now seeking from the Gloucestershire county council. Most of I.C.I.'s existing installations for the manufacture of these products lie in the north, yet much of the consuming market is in the midlands and the south of England; the new factory will be in a good position to supply this market. One of the deciding factors in the choice of the Thornbury site was the availability of good port facilities and it is hoped that tankers of 30,000 tons capacity will bring oil direct from oil-fields and refineries. In many respects the new plant will resemble I.C.I.'s Wilton works in north Yorkshire. Extensive use in it will be made of automatic control, yet it is estimated that the total operating force in the 1970's will be between 4000 and 5000. In design the factory is intended to be a piece of modern industrial architecture whose appearance should not mar the natural surroundings.

New Gas Installations

DURING the year 1956-57 production of gas from oil by public undertakings increased by 16%. Six new oil gasification plants with a total daily capacity of 8.8 million cu. ft. were installed. These included four Onia Gegi plants—two at Fulham of 2 million cu. ft. daily capacity each; one at Hilsea, Portsmouth (2 million cu. ft.) and one at Carlisle (1 million cu. ft.). At Gloucester a Hall plant of 1 million cu. ft. daily capacity and one Jones plant of 0.8 million cu. ft. daily capacity also were installed. During the fourth quarter of the year gas making plant, having a capacity of 28 million cu. ft. was brought into use by the undertakings. This made the capacity of plant commissioned in the year 105 million cu. ft., compared with 104 million cu. ft. in 1955.

B.I.S.R.A. Open Days

MEMBERS and visitors who attended the recent open days of the British Iron and Steel Research Association's Coatings Laboratories at Sketty Hall, Swansea, could not fail to be infected by the enthusiasm of the laboratory staff for their *protégés*, nor, for that matter, their pride in their achievements. Sketty Hall is situated in pleasant surroundings in Singleton Park, close to the University College and is some four miles from Swansea on the Gower Peninsula side. The laboratories, which specialise in research on the coating of steel sheet and strip, are under the direction of Mr. S. S. Carlisle, with Mr. W. Bullough, Dr. M. L. Hughes, Dr. F. W. Salt and Mr. A. G. Shakespeare as senior investigators.

The most outstanding exhibit, and one which was on show for the first time, was that of the pilot plant for producing Plasteel, a P.V.C.-coated steel strip. The laminate is said to combine many of the advantages of both the materials of which it is composed; that its surface resists abrasion, the weather, and corrosion by moisture and chemicals better than paint or enamel. Other advantages are that minor blemishes on the steel's surface which would be unacceptable for painting do not affect the quality of the laminate. Moreover, because of the heat insulation of the thicker film, the P.V.C. surface is warm to touch, unlike painted steel. A similar type of sheet laminate is at present being manufactured commercially in America, although the laminating process developed by B.I.S.R.A. (for which a patent has been applied) produces a material with properties which, for many uses, are said to be superior to the American product. The plastic film is so firmly bonded to the steel that it is scarcely possible to peel them apart without breaking the film. There should be numerous applications for Plasteel in the chemical industry, particularly for chemical containers and storage tanks, and samples of the laminate have been sent to various manufacturers for trials.

Chemical Engineering in Bloomsbury

IF University College, London, has to cede the distinction of organising the first systematic course in chemical engineering to her South Kensington sister (it was organised in 1885 by Armstrong) the Bloomsbury college can at least claim the first chair of chemical engineering to be established in this country, and this fact is, of course, recorded in a short illustrated history of the Faculty of Engineering compiled recently by Professor M. B. Donald, Ramsay memorial professor of chemical engineering. The faculty's history begins virtually with that of University College itself for the "godless" College was established in the 1820's as a result of the ferment of the new ideas and outlooks brought about in large measure by the great technological changes then taking place. Chemical engineering, therefore, came comparatively late in the faculty's history, and it was not until 1923 that the chair in the subject was established through a fund that had been raised to provide a memorial to Sir William Ramsay, occupier of the chair of general and inorganic chemistry at the College, 1887—1913. It had been the research work on the production of nitric acid from nitrogen and hydrogen by the Haber process carried out in the college by the Nitrogen Products Committee of the Munitions Invention Department during the First World War that helped to demonstrate the amount of work that is required to translate a chemical reactor into a mass-production process. This paved the way in Britain for the growth of the study of chemical engineering. A constant help in the development of the faculty at University College has been the support from industry.

Arts and Manpower

THE hope that the "promising project" to establish at Cambridge a combined arts and science honours course would not be allowed to "founder on some of the undoubted difficulties that will be met" was expressed by Sir Alexander Fleck, chairman of I.C.I., at a conference organised by the British Association in Leeds recently on the supply of scientists and technologists for industry. So far as his company was concerned he rejected the charge that is sometimes heard that industry does not use to best advantage its technically-qualified staff and that expensively trained chemists or engineers are found to be in non-technical posts—"edging nearer the till". In his organisation fewer than 3% of the men and women classified as technical management were in fact on the sales or purchasing sides. In any case he could not agree that technical staff were necessarily wasted on those jobs. Those who were going to higher administrative posts would often benefit invaluably from that experience, for it endowed them with flexibility. There were, on the other hand, a number of semi-technical jobs at present filled by technical men which could well be taken by men who had an understanding of scientific principles and scientists. If, as he hoped, school and university education achieved a new balance between science and the arts there would be increasing opportunities to relieve scientists and technologists of this kind of duty.

Non-Destructive Testing

THE development of new methods of the non-destructive examination of solids, liquids and gases involves the establishment of new physical knowledge, and the non-destructive testing group of the Institute of Physics is stimulating interest in the search for this by encouraging discussion on investigations which provide information on the way in which the composition and structure of substances affect their physical properties. The aim of this work is to determine the extent to which the mechanical, chemical and even biological condition of substances can be indicated by physical properties measurable non-destructively. A useful publication just issued by the group is a collection of papers read to it during the past year. It is published as a symposium and is in the form of a supplement to the Institute's official journal. Most of the contents deal with the relationship between the structure of solids and their physical properties or with the measurement of those physical properties which would serve in detecting structural changes. Eight papers on penetrants form a section of the symposium dealing with the physical principles underlying the currently accepted technology of non-destructive testing. They show how little is understood about the principles of penetrant action and how it is impossible, at present, to establish a standard to which fluids should conform for use in the penetrant method of detecting surface defects.

New Plastic Materials

NEW plastic materials, including vulcanised ethylene-propylene copolymers, which have excellent mechanical and chemical resistance, were among new classes of stereoisomer polymers discussed by Prof. G. Natta, Milan, at the sixteenth International Congress of Chemistry held in Paris recently. Specific polymerisation processes discovered during the last three years, he said, had been used to synthesise new classes of polymers that were characterised by regular distribution of the monomeric units in the steric configuration. The kinetic study of the polymerisation reaction, roentgenographic analysis of the catalysts used, study of the complexes containing organometallic bonds catalytically active, *x*-ray investigation of the polymers and the analysis of the end groups by infra-red spectroscopy and radiochemistry, had provided a better understanding of the mechanism of stereospecific catalysis. The isotatical polymers made available new kinds of crystalline thermoplastic materials, which generally had a high melting point and very good mechanical characteristics. Those having a higher melting point yielded, by melting and extrusion, fibres which could be oriented by drawing-out. They possessed "excellent" mechanical properties and were "remarkably interesting from a practical point of view".

Nuclear and Conventional Power Stations

THE possibility of having continuously a range of different types of nuclear power stations under construction was discussed by Mr. J. C. Duckworth, Deputy Chief Engineer (Nuclear Power) of the Central Electricity Authority in an address to the 9th British Electrical Power Convention in Eastbourne recently. Such a plan, he said, might be indicated if nuclear stations of lower capital cost had higher fuel costs, and if some types were more economical for different load factors. Nuclear power stations must be competitive with their conventional counterparts at lower load factors than 75%, he pointed out, if much more than about 9000 megawatts capacity of the plant was to be installed by 1970. It was confidently expected, however, that their efficiency would improve to at least this level. Nevertheless, a great reduction in capital cost per kW. would be necessary before nuclear stations could compete at very low load factors. It was far from certain, therefore, that only nuclear stations could be built after the late 1960's.

Automatic Quality Control

LITTLE progress has been made in the direction of integrating quality control with automatic operation of chemical plants, said Dr. B. W. Bradford, of I.C.I. Billingham Division in a paper read at a congress organised by the Society of Analytical Chemistry at St. Andrews University recently. Success in this direction would depend on the continued elaboration of accurate and reliable instruments, but, although a wide variety of analytical instruments was being made, there was still a scarcity of reliable ones and a failure on the part of instrument manufacturers to appreciate either the potentialities or the difficulties of quality control, he said. At the Billingham Division, the use of optical and mass spectroscopic equipment in analysis had reduced the analytical manpower required by 50%. Installation of other equipment would result in a further saving of 30% in manpower, but the final benefits must be sought in direct application of quality control instruments to process streams. This would eliminate almost all routine analytical control and would bring process analytical data into line with physical operating data such as temperature, pressure, and flow rates which are continuously measured and recorded. Direct application of control analysis methods to process streams was being used successfully at Billingham for the measurement of carbon monoxide, carbon dioxide, hydrocarbons, sulphur dioxide, nitrogen dioxide and chlorine (by infra-red and ultra-violet absorption). A mass spectrometer had been in continuous use there for some time as a full-scale process monitoring instrument on a high-purity argon separation plant. It analyses the gas continuously for methane, hydrogen and nitrogen impurities and carries out periodic analyses of intermediate gas streams.

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Industry's Debt to Fusion Welding

FROM the time of the discovery of the electric arc by Sir Humphrey Davy, more than a century had to pass before the arc process attained the status of a fabrication technique comparable with riveting. Moreover, at the turn of the century neither the arc- nor the gas-welding process was in a position to challenge seriously forge welding and riveting.

The oxy-acetylene process was to be given considerable impetus by the successful liquefaction and distillation of air by Karl Linde in 1902, for this achievement removed one of the main obstacles to its successful development—the impure oxygen which up to that time had been the only available. Linde's historic achievement was followed by the successful pressure generation of acetylene by Fouché, so that for a number of years this process held the lead over metallic-arc processes.

Not until the introduction of the coated electrode a few years before World War I did the process meet with any degree of success. Thereafter followed a period of steady improvement which culminated in two decades of meteoric advance. From all the efforts of the past there has now emerged a variety of highly successful electrical welding processes which, concomitant with advances in metallurgy, have transformed the fabricating industries and conferred immense benefits upon the industries they serve.

Today many engineers, including chemical engineers, are unaware of the history of welding and accept the welded joint with confidence, but a few years ago welding was still viewed with some suspicion. The joining together of metal plates was looked upon as a discontinuity in the material from which a vessel was constructed, and the joint was regarded as a necessary evil thrust upon the equipment maker by the limitations of fabricating methods. This view reflected the lack of confidence, born perhaps of earlier experiences of fusion welding, of occurrences of weld decay in stainless steels and failures with nickel-clad steels. The shortcomings of mechanical and capillary joining methods may have reinforced such views and have lent weight to the designer's motto: "the fewer joints the better". Today, however, the designer, who should yet be cautious, need have few qualms about the quality of the welded joint. In any case, a finished engineering design is not only a compromise between fundamental advantages and disadvantages but a reflection also of the available materials of construction and the technique of fabricating them. Moreover, these two latter factors, together or singly, may limit the scale of operations in a chemical process, and, therefore, its profitability, or they may even decide whether a venture can be carried out at all. So rapid has been progress in welding and the production of new metals and other materials that many of these constructional limitations to design will continue to recede, and, possibly, eventually be eliminated.

An answer to the question "what has fusion welding to offer the chemical engineer?", might well point to achievements of construction in the chemical industry, many of which were undreamt of by the pioneers of welding. Without welding, many varieties of modern chemical plant would not be in existence. The production and handling of nitric and acetic acids, the manufacture of phthalic anhydride, to mention but a few, would be impossible in their present-day forms without successful methods of welding materials like aluminium and austenitic stainless steels.

Another achievement worthy of mention is the fabrication of large-scale plant from polythene and unplasticised P.V.C. by means of hot-gas welding methods. In other industries some of the achievements of welding are even more spectacular. Take, for example, the fast reactor container at Dounreay. This all-welded sphere, the world's largest pressure vessel, measuring 135 ft in diameter and weighing 1500 tons, is an outstanding example of modern welding technique and could not possibly have been made by any other method. The same remarks apply with equal force to the intricate fast reactor itself and its many miles of stainless-steel heat-exchanger pipework.

In the power generating industry also there have been some noteworthy achievements. The main method for attaining high-efficiency power generation based upon steam is to raise the steam pressure of the alternator-driving engines. Some years ago the order of pressures used was a few hundred pounds a square inch, whereas today pressures as high as 1500 psi are quite common. Through this régime of higher pressure it has been possible to double the thermal efficiency of power generation in this country—some stations have an efficiency of over 30%. This advance has been made possible by the development of fusion welding, for it has permitted constructions of a magnitude, a plate thickness and a complexity well out of range of forging and riveting methods of fabrication.

To sum up, the chemical engineer has in fusion welding a technique at his disposal which is free from the limitations of older methods of construction, one providing him with a latitude in design and a choice of structural materials inconceivable in the early 'thirties. It offers superior and cheaper vessels and is a means of producing constructional results unattainable by other methods. It is natural that many new problems in welding and associated ones of stress-relieving will continue to arise, because the demands made upon materials and fabricators are incessant. The appearance of new materials also will bring forward its own problems, which will in time be solved by the proved methods of research, development and plant experience.

LIQUID ATOMISATION IN CHEMICAL ENGINEERING

by R. P. FRASER, O.B.E., M.I.Chem.E., P. EISENKLAM, Ph.D., M. Eng.Sc., and N. DOMBROWSKI, Ph.D., A.M.I.Chem.E.

In this introductory article the authors deal with liquid disintegration and the dispersion process and a study of the various types of atomiser is made

CHEMICAL engineers are concerned with liquid dispersion in numerous liquid-gas contact operations, such as distillation, liquid absorption or desorption, humidification, spray drying, spray crystallisation, combustion and gas scrubbing, etc. In these operations a multitude of equipment is used to prepare the phases, so that contact between their molecules takes place at a controlled rate and in a controlled manner. Packed columns, tray columns, vaporisers, combustion chambers, spray chambers, etc., are all designed to achieve a suitable increase in specific surface of the liquid, as well as efficient contacting and, where necessary, a final separation of the phases. Amongst the methods used to produce a large interfacial surface is the process called "atomisation"—by which very rapid and efficient liquid-gas contact is achieved.

The disintegration of liquids by the process of atomisation is commonly employed in three major industries: combustion engineering, agriculture and chemical engineering. Atomisation of liquid fuels for combustion is about a century old and interest is confined to hydrocarbons having a small variance of physical properties. In agriculture the interest is mainly in aqueous solutions and means to convey the spray a long distance; whereas in chemical engineering a knowledge is required of the effect of a wide variation of physical properties of the liquid and atmosphere.

Today it is necessary to atomise and distribute, with control, a multitude of liquids, the properties of which range from those of chemical solutions, emulsions and dispersions, to slurries and even gels. The chemical engineer has to apply his knowledge of the handling of these liquids, and of the fluid kinetics of rapidly moving jets and sheets, in order to design suitable processing equipment. The majority of atomisers commonly employed in chemical engineering were designed for simple liquids, namely, inviscid Newtonian liquids. When they are employed for slurries, pastes and liquids having anomalous properties, there is a great deterioration in performance and, in many cases, they may be rapidly eroded and damaged to become quickly useless. Thus, much is to be gained by a study of the various types and designs of atomiser so that a suitable selection can be made for the duty to be performed.

While the production of a large surface area fulfils an important requirement of many processes, efficient operation can only be achieved if the particles are of a specified size and, what is perhaps more important, have a high degree of uniformity. Only if these conditions are fulfilled can the design be on a rational basis and the operation carried out under controlled conditions. If, in spray drying, drops of one size could be produced, their drying rates and their flow pattern would be uniform and easily

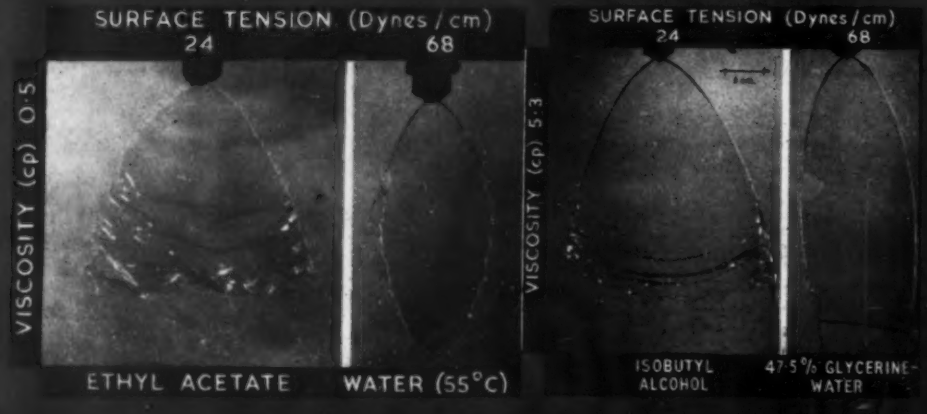


Fig. 1(a). Liquid sheet formation from fan spray nozzles, showing the viscosity, surface tension

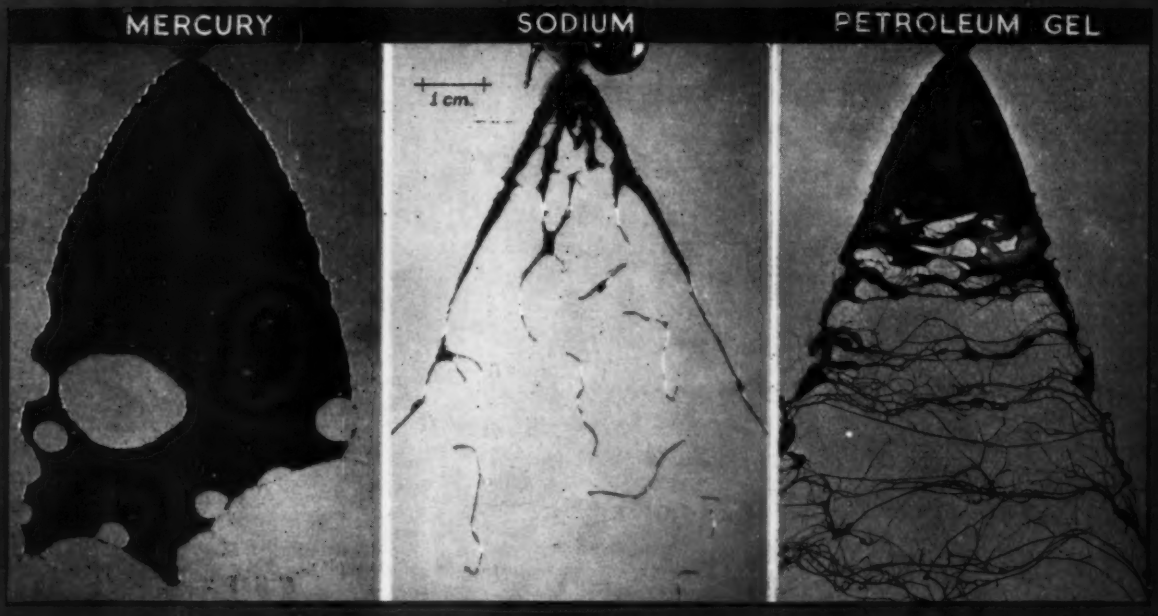


Fig. 1(b). Liquid sheet formation from fan spray-nozzles using unusual liquids.

established. The drying chamber could therefore be accurately designed with the full knowledge of the heat and mass requirements. In practice, however, a wide size range is produced and difficulty in operating the drying chamber is experienced if this range is too great. As the capacity of the drier is dependent upon the time required to dry the largest drop during its flight, it is therefore necessary to control the mass and heat transfer by a selection of the size of the largest drop and the size dispersion of the spray; small reductions in drop size will greatly change the rate of evaporation. Again, during the decelerating flight of a drop, evaporation is practically independent of the initial drop size and any drop velocity can be used to obtain the required drop size of the atomiser and to satisfy the geometry of the drier.

Classification of Atomisers

Because of the development and particular usage in the industries previously mentioned, considerable confusion exists regarding atomiser terminology. Table 1 has been devised in an attempt to reduce the number of terms applied to particular forms of atomiser, and to encourage the use of unambiguous definitions. In this table atomisers are classified according to the energy employed for disintegration, and it is convenient to discuss them in order under these three headings.

The demand for simplicity often sways the choice towards pressure nozzles, and if the liquid has a low viscosity this type operates very satisfactorily. The spatial dispersion from pressure nozzles can be made to vary by altering the hydraulics of flow in the orifice and also by arranging a number in different patterns. On the other hand, twin-fluid atomisers can deal with more viscous liquids, but they operate at their best when producing very small drops which are often not required. The twin-fluid atomiser of the simplest venturi type is commonly used for spraying viscous materials in the paint and plastics industry. Variation of spray form is usually obtained, in this case by changing the area and shape of the air stream.

It is often thought that rotary atomisers produce a more uniform spray than others, but, in practice, under comparable conditions of throughput and velocity, similar size distributions are obtained.

By reason of the various duties required, a number of complex types of atomiser have been designed. These devices usually combine two sources of energy. For example: a swirl spray nozzle is combined with a medium-pressure twin-fluid atomiser to give greater flexibility or turn-down ratio, and reduce the drop size. A spinning disc or cup is combined with a low-velocity air stream to increase the disintegration and give forward projection. All forms of pressure atomisers may be combined with a gaseous medium at low pressure to give control of drop direction and particle size.

The common industrial usage of atomisers is shown in Table 2. In general, where relatively coarse sprays and simplicity are required, the device employed is the simpler form of pressure nozzle. On the other hand, where the liquid is viscous and is difficult to disintegrate, high-energy atomisers of the rotary and twin-fluid type are employed.

Mechanism of Disintegration

The main principle of the disintegration of a liquid consists in increasing the surface area of a rod or sheet until it becomes unstable and disintegrates. By this process, a cylindrical jet at low velocity breaks up into relatively large drops. To obtain smaller drops from a cylindrical jet high velocities have to be employed, and disintegration then occurs largely by the formation of thin threads which are drawn out of the main rod by air friction. A similar process occurs with twin-fluid atomisers, where the threads are torn off the slower-moving liquid by the surrounding high-velocity air stream.

The method usually employed to produce small drops at lower working pressures and velocities is to design the nozzle so that the liquid is sprayed into a thin sheet. The sheet may be only 1-5μ thick and disruption occurs when the depth of any disturbance in the sheet is of the order

TABLE 1. CLASSIFICATION OF ATOMISERS

Centrifugal energy used for rotary atomisers	Pressure energy used for pressure atomisers	Gaseous energy used for twin-fluid or blast atomisers
Spinning Cups 20-100 ft/sec.	FAN-SHAPED SPRAYS:	*Low Pressure* (0.25-2 lb/sq in.):
	Fan Spray Nozzles (Single Orifice) 25-125 lb/sq. in.	Gas velocity 100-400 ft/sec.
	Impact Nozzles	Gas/liquid ratio 15-25 lb/lb.
	Impinging Jet Nozzles 20-140 lb/sq. in.	
	Solid Surface Impact Nozzles up to 400 lb/sq. in.	
	Deflector Nozzles 1000 lb/sq. in.	*Medium Pressure* (2-20 lb/sq. in.):
Spinning Discs		Gas velocity 400-1000 ft/sec.
Flat Discs		Gas/liquid ratio 0.2-1 lb/lb.
Saucer-shaped Discs	CONICAL-SHAPED SPRAYS:	*High Pressure* (above 20 lb/sq. in.):
Radial-vaned Discs	*Swirl Spray Nozzles* (Hollow Cone) (Drowned Cone)	Gas velocity sonic or above
Multiple Discs	40-1000 lb/sq. in.	Gas/liquid ratio 0.2-1 lb/lb.
100-600 ft/sec.	*Divergent Pintle Nozzles* 20-1000 lb/sq in.	

TABLE 2. COMMON INDUSTRIAL USAGE OF ATOMISERS

1. Rotary Atomisers	6. Deflector Nozzles	*Blast*
2. Rotary and Air	7. Plug or Plate Type (hollow cone)	11. Low-pressure Twin-fluid
Pressure	8. Single Port (hollow cone)	12. Medium-pressure Twin-fluid
3. Single Orifice Fans	9. Solid Cone Spray	13. High-pressure Twin-fluid
4. Impinging Jets	10. Pintle (hollow cone)	
5. Solid Surface Impact		

Aerosols	12, 13	Intermittent sprays: fuel	9, 10
Aerating water	9, 8		
Agricultural usage	all	Jet engine combustion chamber	7
Case hardening	9		
Coke cooling	9	Lubricating	13
Conveyor-belt systems	3		
Cooling ponds	8	Metal spraying	12, 13
Cooling towers	8	Metal powders	13
Degreasing (alkali wash)	3	Oil burning (distillates)	7, 11, 12
Descaling	6	Oil burning (heavy oils)	12, 13, 2
Desuperheaters	7	Oil gas generators	12, 13
Disc washing	9, 3		
Distillate enrichment of coal gas	9	Paint spraying	12
		Perfumery	3, 12
Dust laying	9, 6	Petrol injection	7
Fire-bar cooling	3	Quenching	9
Fire protection (general)	10 4, 7 (clusters)	Rinsing	9, 3
		Rocket combustion chambers	4, 11
Fire protection (transformers)	9, 8		
Foam breaking	9, 6	Spray evaporators	3, 5
		Spray drying (general)	7, 1, 2
Gas scrubbing	1, 7, 9	Spray drying (slurries)	1, 2
Gravel washing	3	Sulphur (molten) spraying	12, 8
Humidifying (direct)	13, 5	Vehicle washing	3
Humidifying (indirect)	8	Vessel coating	7

of this thickness. With a non-viscous liquid threads are formed which have their greatest instability when the length is 4.5 × diameter. Turbulent flow conditions may also exist in the nozzle, and when the velocity of the sheet is high the effect of the ambient atmosphere is superimposed on the above factors, making for instability.

Spray Sheet Development

The development of conical sheets from swirl spray-nozzles has not been so well explored as the laminar sheet from fan spray-nozzles. The effect of the ambient atmosphere can be expected to be similar in both cases, but the development of the sheet from a swirl spray-nozzle will depend on the cone angle. The development of the spray sheet is influenced by both the ambient atmosphere and the liquid properties. In a fan spray-nozzle the extent of the sheet is controlled at the boundary by the equilibrium between the momentum along the streamlines and the contraction of the edges as a result of the action of surface tension. The sheet develops as it travels from the orifice, but its velocity remains constant and its thickness, therefore, diminishes. With increasing pressure differential, the sheet develops until a constant angle and a maximum length is reached. On further increase of pressure, the break-up length of the sheet diminishes. The influence of liquid properties is such that an increase in viscosity lengthens the sheet and an increase in surface tension contracts it, but makes it more placid. This is demonstrated in Fig. 1 (a), where the sheets produced from fan spray-nozzles are compared at equal velocities. The four sheets are arranged in a viscosity : surface-tension classification. With liquid sodium, which has a high surface tension, the effect is so marked that the sheet disintegrates very near to the nozzle into a series of rods and shreds. Petroleum gel fits into the high-viscosity, low-surface tension group, but the drops are replaced by longitudinal tenacious threads. Mercury, with its very high surface tension, does not fit this picture at all because of its high density which causes a highly resistant long sheet to be produced. The sheet obtained from the above three liquids is shown in Fig. 1 (b).

The effect of ambient atmosphere is superimposed on the effect of liquid properties. Spraying into a reduced atmosphere, for instance, will result in greatly elongated sheets and vice versa.

Expansion of Liquid Surfaces

The rate at which atomisation expands the liquid surface is very great. A sphere of 1 cm diameter contains a volume of about $\frac{1}{2}$ cc with a surface area of

3.14 sq. cm. If it is disintegrated into 10,000 equal spheres, they will have a diameter of 470 μ, approximately $\frac{1}{2}$ mm, and this process is coarse atomisation. In general, the mean particle size range for atomisers is between 20 and 500 μ; above this, the apparatus is commonly defined as a "sprinkler". The factual increase of surface area in the atomising range is about 250 to 5000 times. Fig. 2 shows the equivalent surface area against drop diameter for 1 cc of liquid. The very great rate at which the surface area increases below 50 μ accounts for the fact that much greater energy has to be used to obtain the smaller particles, as will be seen later.

Drop Size from Atomisers

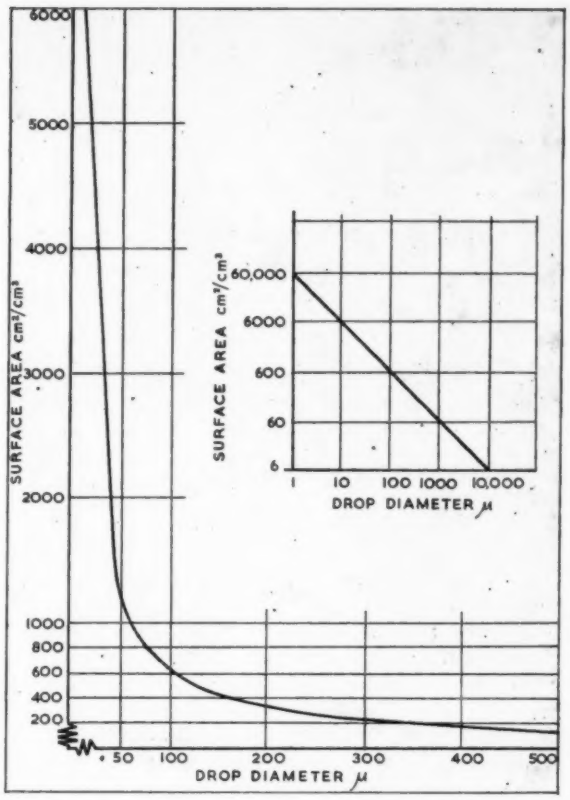
One of the most sought after and most abused performance criteria of an atomiser is the size of the drops in the spray. Not only does atomiser design and the physical properties of the liquid and ambient spraying atmosphere influence the drop formation and dimension, but there are also transient effects to be considered which affect the drops' life history during flight, such as evaporation, coalescence and secondary disintegration by air friction. When quoting drop-size results it is necessary, therefore, to specify the method of drop-size determination and the ambient spraying conditions. Furthermore, a spectrum of sizes is obtained and its mean and size dispersion is of interest. For more precise information the drop size distribution ought to be given because the mean and the size dispersion do not give complete information of the size spectrum.

With so many factors which can influence the drop size, it is not to be wondered that accurate information is difficult to obtain. The data which are available are generally limited to specific operating conditions and techniques of measurement, and much guess-work and intuition are required to estimate results under different conditions. Although present-day techniques of drop-size determination allow a fairly accurate estimate of the drop size under most operating conditions, the actual requirements for most applications are only very vaguely known. Such ignorance has fostered the notion, which is firmly established, that the actual drop size required is often very immaterial to the process, provided "good" atomisation takes place, or provided the number of drops of smallest or largest size is controlled. Hence, much of the effort which, in the past, has been directed towards determining the drop size from existing sprayers should now be directed towards establishing the drop-size requirements for particular liquid-gas contact processes in which atomisers are used.

Effect of Ambient Conditions

For spraying into a stagnant atmosphere where movement is brought about only by entrainment, the density of the medium is one of the most important factors affecting drop size. As to the effect of gas viscosity, it is known that within the limits of 7-35 cs. the drop size of single-hole injector-nozzles of the diesel type operating at 1500 to 2000 lb/sq. in. is hardly affected. Little is known outside this range of gas viscosity, although in combustion applications much higher values are likely to exist. The effect of gaseous density has been more extensively studied. With the above-type nozzle, a 35% decrease in drop size occurs for a 42 times increase in air density, corresponding to a raising of the pressure at room temperature from atmospheric to 600 lb/sq. in. Similarly, a 20% increase in drop size occurs with a fan spray-nozzle of FN = 0.74, by reducing the density from atmospheric to a vacuum.

Fig. 3 shows the drop-size results from such a nozzle at atmospheric density and at near vacuum conditions with varying differential injection pressures. The percentage



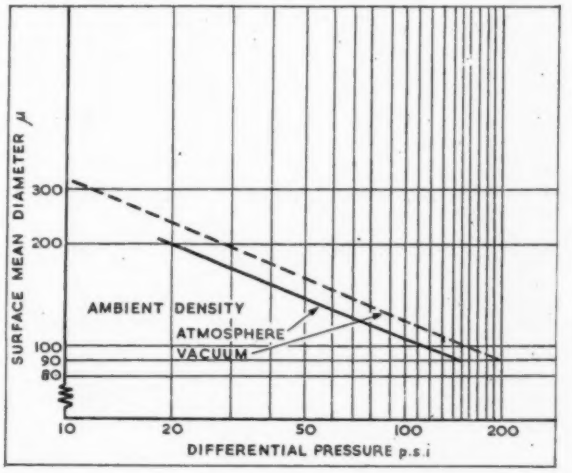


Fig. 2 (top). Rate of increase of specific area on reduction of drop diameter. Fig. 3. Drop size from a fan spray-nozzle.

increase in drop size is unaffected by differential pressures. The change in drop size with absolute density is not gradual, but a discontinuity occurs at a density of about 0.04 lb/cu. ft (15 in. mercury absolute at room temperature) as a result of a marked change in the mode of disintegration of the liquid sheet.

(Subsequent articles in this series will deal with the rotary, pressure and twin-fluid types of atomiser.)

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SASOL:

WORLD'S LARGEST OIL-FROM-COAL PLANT

by J. C. HOOGENDOORN and

J. H. SALOMON, B.Sc. (Eng.), Ph.D.

In the last article of the series* the authors describe the recovery of subsidiary products at this South African oil-from-coal plant

DURING the cooling of the gas produced in the pressure gasification of coal, a large quantity of condensate separates out. This stream contains light oils (almost entirely aromatic), tar and gas liquor. The ratio of water to tar in this stream is high; only about 40% of the steam fed to the gasifiers reacts to form hydrogen and methane, the remaining 60% passes through unreacted and this forms the bulk of the condensate. A typical analysis of the total condensate is: 98.3% water; 0.3% oil; and 1.4% tar.

This condensate is obtained hot and at a pressure of 300 psig. When the pressure is released in a separator, a vapour consisting of light-oil and water is evolved. This vapour is condensed and then separated in a separating tank. The remainder—the bulk—of the condensate is gravity separated in a tank. Altogether, three streams of condensed products are obtained:

(*a*) gas liquor;
(*b*) tar; and
(*c*) light aromatic oil.

These streams are treated to recover the commercially saleable products present and, with the gas liquor, to produce a waste-water stream which is sufficiently pure for disposal. The treatment of the gas liquor will be considered first

Phenol Extraction Plant

The average content of the gas liquor is 8500 parts per million (p.p.m.) of ammonia and 1800 p.p.m. of tar acids. The total quantity of gas liquor is about 25,000 gallons an hour. Prior to recovery of the ammonia, the liquor is first treated to remove the phenols present. For this purpose, Sasol operates a parallel, two-stream, Lurgi-designed Phenosolvan plant. The gas liquor is first freed of residual tar and oil by gravity separation followed by sand filtration. The filtered liquor is then extracted with butyl acetate in a seven-stage countercurrent horizontal extractor. To avoid hydrolysis of the butyl acetate during the extraction, it is important to maintain the *p*H of the liquor at about 8.5. This is done by saturating the gas liquor, before extraction, with carbon dioxide.

The main stream of extracted gas liquor is stripped of the dissolved butyl acetate with live steam in a Raschig-ring-packed stripping tower. The top temperature is kept at approximately 185°F, at which all butyl acetate is stripped off while the bulk of the ammonia is retained in the gas liquor. Overheads from the tower, which consists of butyl acetate, water vapour and a considerable amount of carbon dioxide, is scrubbed with a part of the extracted gas liquor to recover the butyl acetate. For this purpose, also, a ring-packed tower is used. The bottom of this tower is constructed as a separator. The residual vapour stream, containing carbon dioxide, is used to control the *p*H of the incoming gas liquor in a saturation tower.

Subsequent to the removal of the butyl acetate, the gas liquor is stripped of ammonia—which is mainly present as free ammonia—and the purified liquor, now containing about 2 p.p.m. of phenols and 300 p.p.m. of ammonia, leaves the plant. This is treated biologically before disposal. The ammonia vapour produced in the ammonia stripper tower consists of approximately 6% ammonia, some carbon dioxide and steam. This ammonia vapour is worked up to ammonium sulphate in a conventional coke-oven-plant-type saturator. This process is well known and the plant will not be described here.

Rich butyl acetate (containing the extracted tar acids) from the extractors is treated first in an atmospheric and then in a vacuum distillation tower. The butyl acetate is then re-used in the process. The bottom product of the vacuum tower is crude phenol of the following average composition:

Phenol (carbolic acid)	40%
Cresols	30%
Xylenols	7%
Higher boiling tar acids	23%

At present this product is sold in the crude form.

The energy consumption of this plant is low; the butyl acetate consumption is around 200 g/m³ of treated gas liquor.

Tar Distillation

The tar and light-oil recovered in the gas liquor separation section of the gasification are combined and worked up together in the tar-distillation plant. This plant consists of two continuous-distillation towers, the first working at atmospheric pressure, the second under reduced pressure—1 in. mercury absolute. The reboilers and feed heaters of both columns are heated by heat-transfer oil (of the Dowtherm type) which, in turn, receives its heat from a gas-fired furnace.

The overheads of the atmospheric column consists of water and oil (mainly aromatic). After condensation and separation of the water, the oil is passed to a hydrogenation unit for refining and hydrodesulphurisation. The vacuum tower separates the bottoms of the atmospheric column into a bottoms product of pitch and an overheads and side stream of creosote and road tar prime respectively.

* *The previous articles were published in* British Chemical Engineering, *May, p. 238; June, p. 308; and July, p. 368.*

Gas Naphtha Hydrogenation

As was mentioned in the first article (*British Chemical Engineering*, May, p. 238), in the Rectisol gas-purification plant a certain amount of aromatic oil, referred to as naphtha, is separated from the pre-wash methanol. This naphtha, together with the overheads of the tar-distillation atmospheric tower, forms the feed to the gas-naphtha hydrogenation plant. The object of this plant is to remove, by hydrogenation, gum-forming substances and phenols from the aromatic oils. In addition, the sulphur compounds contained in the naphtha are converted to hydrogen sulphide and can easily be removed by washing with alkali. Hydrogenation takes place in the vapour phase over a fixed-bed catalyst at a pressure of about 750 psig and a temperature of 600-700°F. As a hydrogenation medium, pure hydrogen or a hydrogen-containing gas—such as Fischer-Tropsch synthesis gas—can be used. The oil, together with hydrogen-containing make-up gas, is heated by heat-transfer oil and evaporated in an evaporator into which hot recycle "hydrogen" is blown. The gas and oil-vapour are then, after further heating to the required temperature, passed into the hydrogenation reactor. This consists of an outer shell fitted with steel baskets containing the catalyst.

To ensure an even temperature distribution in the reactor, cold recycle gas can be introduced as quench gas at several points in the reactor. The hydrogenated product is cooled and separated from the excess gas, a part of which is recycled, after heating by heat exchange with the hot reaction product, to the evaporator. The liquid product is expanded to atmospheric pressure and subjected successively to a caustic wash, water wash, sulphuric acid wash and a final water wash.

The hydrogenated, washed naphtha can be worked up in two different ways:

(1) Distillation to "motor benzol" by removal of the heavy ends, i.e., the fraction boiling above the F.B.P. of the desired grade of petrol.

(2) Fractionation to give benzol, toluol, xylol, neutral creosote and heavy naphtha. These are saleable as solvents.

Most of the chemicals produced as subsidiary products of the hydrocarbon synthesis are separated by continuous distillation as described in the third article of this series (*British Chemical Engineering*, July, p. 368). Some of these chemicals arise, however, in such small quantities that continuous distillation plant is not economically justifiable. For working-up of these products, Sasol has at its disposal two batch-distillation units. The feed to these batch stills can be, for example:

(*a*) Mixtures of heavy alcohols—butanol and higher; (*b*) hydrogenated naphtha as mentioned under method (2) above; and (*c*) mixtures of water, acetone and methyl-ethyl ketone (in which case the mixture would be dehydrated and separated into pure acetone and pure methyl-ethyl ketone). The stills are of the bubble-cap type and can be operated either under atmospheric or elevated pressures.

Acids Recovery

The fatty acids produced in the synthesis are obtained as a dilute—usually less than 1%—aqueous solution. To prevent steam volatilisation during concentration, the acids are "fixed" by neutralisation with alkali. The resultant dilute solution of fatty-acid salts is concentrated in a triple-effect evaporator. The discharge from the third effect is a concentrated—better than 50%—solution of the salts. At present this concentrated solution is destroyed with recovery of the alkali, but, in future, the acids will also be recovered. This will be done by preparing the anhydrous acid salts from the 50% solution and regeneration of the acids, followed by distillation to yield the pure acids. This latter process is in the pilot-plant stage at the moment.

Conclusion

Although it is not possible in such a short series of articles to enter into great detail of the Sasol enterprise, and many details must, of necessity, be withheld, sufficient information has been made available for some idea of the complexity and integrated nature of Sasol to be obtained. The proven success of the undertaking, after the solution of the problems which once made the Fischer-Tropsch process uneconomic, holds promise for countries without indigenous oil supplies and with supplies of cheap coal or natural gas.

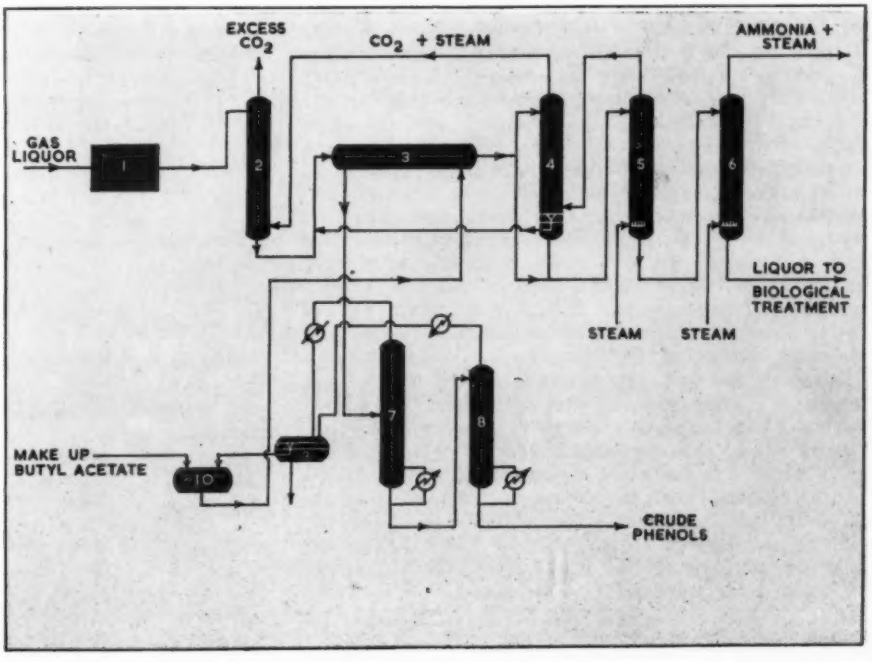


Fig. 1. Phenosolvan plant —only one stream shown.

KEY

1. Tar-oil separation (gravity).
2. Saturation tower.
3. Phenol extractor.
4. Butyl acetate recovery tower.
5. Butyl acetate stripping tower.
6. Ammonia stripping tower.
7. Atmospheric distillation tower.
8. Vacuum distillation tower.
9. Separator drum.
10. Butyl acetate circulating drum.

APPLICATION OF AUTOMATIC PROCESS CONTROL TO CHEMICAL ENGINEERING

Part 3: Response to a fluctuating disturbance*

by N. J. HASSETT, Ph.D., M.I.Chem.E.†

IN the previous article, the response of a thermometer to an incremental or step change and a steadily increasing change was discussed. The time-constant L was derived and its significance explained. Suppose now that water is maintained at a temperature fluctuating between 190 and 210°F by applying or removing a source of heat as the limiting temperatures are approached. If the thermometer at room temperature is suddenly plunged into the water, there are two distinct reactions. The first is a rise of indicated temperature towards the temperature range of the hot water, and the second is the reaction to the temperature fluctuation. Initially, the rise of indicated temperature predominates because the temperature difference is large as compared with the fluctuation. As the thermometer temperature nears that of the hot water, the second reaction becomes relatively more important until finally the second reaction takes over completely and the thermometer attempts to follow the fluctuation around 200°F.

The thermometer response is illustrated in Fig. 2. Its temperature increases approximately exponentially until it comes into the hot-water temperature range. Thereafter, it follows the fluctuation, but, because of its inherent lag in measurement, it falls behind and only registers the true temperature where the paths cross. On the thermometer temperature curve the first meeting point is at some arbitrary point A depending on the precise moment at which the thermometer was immersed in the hot water. In approaching A, the rate of thermometer temperature rise slows down as the actuating temperature difference, θ, decreases, until at A, where θ is zero, the thermometer reaches its first maximum reading and then starts falling. It continues to fall for as long as θ is negative, with the rate of fall proportional to θ. As the water temperature passes its minimum value and commences to rise, so θ and the rate of thermometer temperature fall decrease until, at B, θ is again zero and the thermometer has reached its first minimum value. By then the system has settled down to a regular rhythm. The process repeats and, at C, the thermometer reaches its second maximum reading. It is seen that the thermometer reading fluctuates with the same frequency as the hot water, always lagging behind and indicating temperatures closer to the mean value than the true temperature fluctuation. It is a logical inference that the slower the response (i.e., the larger the time-constant L of the thermometer), the greater will be the lagging behind and the narrowing of the apparent temperature fluctuation band. The lag of the indicated temperature curve behind that of the true temperature is known as the phase lag, and the proportional reduction in amplitude, the attenuation.

Fluctuating disturbances and responses in process systems usually smooth themselves out to approximate sinusoidal form, so before proceeding with the quantitative treatment of frequency response the relevant mathematical background will briefly be reviewed.

Typical sine and cosine curves are shown in Fig. 2 and may be considered with reference to Fig. 1. The circle in Fig. 1 has been divided into four quadrants and a radius OP is rotating anti-clockwise at a constant rate w radians per unit time. OP traverses 2π radians (natural units) or 360° in a time period τ. The angle x defining the position of P is measured from OA if A is the location of P at zero time. Then

2π radians = 360° and 1 radian = 57.3°.

Frequency of cycle = $\tau = w/2\pi$.

$x = wt. = 2\pi t$ in radians = $360t/\tau$ in degrees.

AA_0 and BB_0 in Fig. 1 are regarded as conventional graphical axes with zero origin at O, and the rotating arm OP is considered as always positive. The perpendicular PC is positive above AA_0 and negative below it. The intercept OC is positive along OA_0 and negative along OA. The signs of the trigonometrical ratios $\sin x = PC/OP$ and $\cos x = OC/OP$ according to the position of P then follow. It is seen that both $\sin x$ and $\cos x$ have maximum and minimum values of +1 and −1. Inspection shows that if x is between 90 and 180, $\sin x = \sin (180 - x)$,
180 and 270, $\sin x = -\sin (x - 180)$,
270 and 360, $\sin x = -\sin (360 - x)$,
and since trigonometrical tables are given up to 90°, x must be reduced to below 90° in order to determine the numerical value of its trigonometrical ratio.

Example 8

What values of x give (*a*) $\sin x = 0.454$, and (*b*) $\cos x = -0.454$?

(*a*) Since $\sin x$ is positive, x must be in first or second quadrant.

From tables, $\angle x = 27°$. x can be 27° or 180 − 27° = 153°.

It can also be $360n$ above or below these values. The series above 0° is 27°, 153°, 387°, 513°.

(*b*) Since $\cos x$ is negative, it must be in the second or third quadrant.

From tables, $\angle x = 63°$. x can be 180 − 63° = 117° or 180 + 63° = 243°. The complete series above 0° is 117°, 243°, 377°, 603°, ...

Fig. 2 shows that the cosine curve is identical with that

* Previous articles were published in *British Chemical Engineering*, May, pp. 253-255, and June, pp. 313-315.

† Senior Lecturer at Loughborough College of Advanced Technology.

Automatic flow controllers controlled by volumetric governors in the control room of the North West Gas Board's smokeless-fuel plant near Manchester.

of the sine curve, but displaced by 90°. It is also noted that the ordinate can equally well be a time, radians or degrees scale, as shown on Fig. 1.

The equation governing the response of the thermometer as described earlier can now be derived. As shown in the second article (p. 314), the thermometer temperature rise or fall in an infinitesimal time period dt is given by Equation (2).

$$dT' = \frac{UA}{C}\,\theta\,dt = dt/L \qquad \ldots.(2a)$$

The fluctuating temperature of the water can be written as

$$T = T_m + X_0 \sin 2\pi t/\tau = T_m + X_0 \sin (wt) \qquad \ldots.(12)$$

where T_m = mean water temperature;
X_0 = amplitude of temperature fluctuation; and
τ = period of the fluctuation.

In infinitesimal time dt, the water temperature changes by $X_0\,d\sin(wt)$, so that the change in θ is given by

$$d\theta = X_0\,d\sin(wt) - dT' \qquad \ldots.(13)$$

$$= X_0\,d\sin(wt) - \theta\,dt/L \quad \ldots.(\text{c.f. Equation (2a)})\,(14)$$

$$d\theta/dt - \theta/L = X_0\,d\sin(wt)/dt = X_0\,w\cos(wt) \qquad \ldots.(15)$$

This is the fundamental differential equation governing the response of the thermometer. A similar sort of equation governing the response of a process stage to a disturbance can be derived from general stoichometric considerations, and this is where a control design problem can often be handed over to the control instrument technologist. It is desirable, however, that the chemical engineer should be able to develop it further.

The solution of Equation (15) will now be examined analytically and quantitatively. Methods of solving the fundamental differential equation will be discussed in a later article. The complete solution for θ, the measurement error in terms of t, is:

$$\theta = \left(\theta_0 - \frac{X_0\,wL}{(1+w^2L^2)}\right)e^{-t/L} + \frac{X_0\,wL}{(1+w^2L^2)^{\frac{1}{2}}}\sin\left(wt + \tan^{-1}\frac{1}{wL}\right) \qquad \ldots.(16)$$

The first term of the right-hand side is the transient solution representing the initial response of the thermometer. The similarity to Equation (5) in article 2 (p. 314), response to a step change, is apparent. The transient solution dies away as t increases. The second term of the right-hand side is known as the steady-state solution. It is a sinusoidal oscillation of amplitude $\frac{X_0\,wL}{(1+w^2L^2)^{\frac{1}{2}}}$ with a phase advance of $\tan^{-1}\frac{1}{wL}$ ahead of the water temperature oscillation.

Example 9

A thermometer with time-constant L = 0.43 min. (as in Example 6, p. 315) reads 70°F and is suddenly plunged into hot water at 200°F as the water temperature is on the upwards swing of a regular fluctuation between 190° and 210°, each complete cycle being of two minutes' duration. What are the recorded temperatures after 26 and 30 seconds and at every subsequent half minute?

The recorded temperature T' is given by

$$T' = T - \theta = T_m + X_0 \sin(wt) - \theta \qquad \ldots.(17)$$

$$= T_m + X_0 \sin(wt) - \left(\theta_0 - \frac{X_0\,wL}{(1+w^2L^2)}\right)e^{-t/L} - \frac{X_0\,wL}{(1+w^2L^2)^{\frac{1}{2}}}\sin\left(wt + \tan^{-1}\frac{1}{wL}\right) \qquad \ldots.(17a)$$

In equations of this type it is helpful to regard the radian as a dimensionless ratio, but the degree as not. Other units must be consistent; if t is in seconds, L must be also. It is convenient here to work in seconds. The data will first be put in working units and the various terms evaluated and tabulated. Equation (17a) becomes $T' = T_m + A - (B + C)$ for convenience of tabulation.

Thus:

$T_m = 200°\text{F}$;
$\theta_0 = 200 - 70 = 130°\text{F}$;
$\tau = 120$ secs.;
$X_0 = 210 - 200 = 10°\text{F}$;
$w = \frac{2\pi}{\tau} = \frac{2\pi}{120} = 0.052$ rads-secs.
$wt = \frac{360t}{120} \times 57.3t = 3t$ degrees;
$L = 0.43$ min. $= 26$ secs.;
$wL = 26 \times 0.052 = 1.35$;
$w^2L^2 = 1.82$ $\qquad (1 + w^2L^2)^{\frac{1}{2}} = 1.68$; and
$\tan^{-1}\frac{1}{wL} = \tan^{-1} 0.74 \simeq 37°$.

Equation (17a) then resolves to:

$$T' = 200 + 10\sin 3t° - [125.2e^{-t/26} + 8\sin(3t + 37)°] \qquad \ldots.(17b)$$

$$= 200 + A - [B + C] = T - \theta.$$

Tabulating the various terms:

t	$e^{-t/26}$	B	$(3t+37)$	$\sin(3t+37)$	C	A	T	θ	T'
0	1	125.2	37°	0.60	4.8	0	200	130	70
26	0.37	46	115	0.91	7.28	9.9	209.9	53.3	156.6
30	0.30	38	127	0.80	6.4	10.0	210	44.4	165.6
60	0.1	13	217	−0.60	−4.8	0	200	8.2	191.8
90	0.03	4	307	−0.80	−6.4	−10	190	−2.4	192.4
120	0.01	11.3	397	0.60	4.8	0	200	6.1	193.9
150	0.003	0.4	487	0.80	6.4	10	210	6.8	203.2
180	0.001	0.1	577	−0.60	−4.8	0	200	−4.7	204.7
210	0.0003	—	667	−0.80	−6.4	−10	190	−6.4	196.4
240	0.0001	—	757	0.60	4.8	0	200	4.8	195.2
270	—	—	847	0.80	6.4	10	210	6.4	203.6
300	—	—	937	−0.60	−4.8	0	200	−4.8	204.8
330	—	—	1027	−0.80	−6.4	−10	190	−6.4	196.4
360	—	—	1117	0.60	4.8	0	200	4.8	195.2

The curve for T' is plotted in Fig. 1

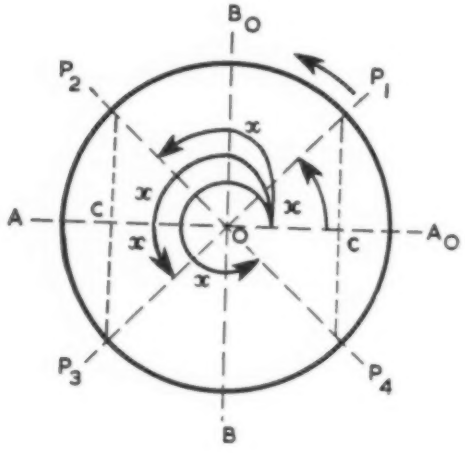


Fig. 1. Circular diagram for trigonometrical ratios.

Example 10

In the previous example, what are the maximum and the minimum steady-state temperatures of the thermometer and when do they occur?

When steady state is reached, the transient response (term B) has died out. From the table this is seen to be at about 180 seconds.

The maximum and minimum temperatures are found by first differentiating Equation (17b), omitting the exponential term.

$$T' = 200 + 10 \sin(3t)° - 8 \sin(3t + 37)° \quad \ldots (17c)$$

$$dT'/dt = 30 \cos(3t) - 24 \cos(3t + 37) = 0.$$

Rearranging and expanding:

$$1.25 \cos(3t) = \cos(3t) \cos 37 - \sin(3t) \sin 37$$
$$= 0.80 \cos(3t) - 0.60 \sin(3t)$$

whence $\tan(3t) = -0.45/0.6 = -0.75$.

$(3t)$ is in second or fourth quadrant and from tables $(3t) = 37°$

$$(3t) = n\pi - 37° \text{ where } n \text{ is any integer.}$$

Substituting in Equation (17c):

$$T' \text{ max. and min.} = 200 \pm 10 \sin(n\pi - 37°) - 8 \sin(n\pi)$$
$$= 200 \pm 6.02 - 0 = 206°\text{F and } 194°\text{F.}$$

These values occur at 37° before the $n\pi$ ordinates, as shown in Fig. 1. The maxima and minima of the T curve occur 90° before the $n\pi$ ordinates, so that the T' curve lags $90 - 37° = 53°$ behind the T curve.

Integration of the Differential Equation

Of the available methods for solving the governing differential equation, that using Laplace transforms is recommended. It can be regarded as analogous to the use of logarithms and antilogarithms for computation. The differential equation can contain terms with the unknown required quantity θ in different orders of differentiation, and the time variable bound up in complex expressions. Each of these terms has a corresponding term which can be found in a table of Laplace transforms, the constants

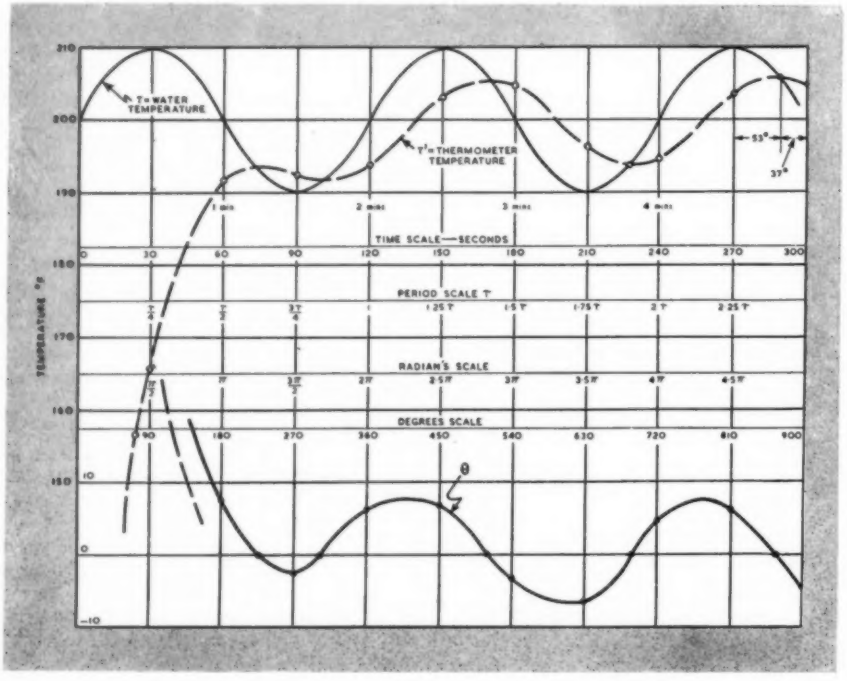


Fig. 2. Typical sine and cosine curves representing response of thermometer to cyclic disturbance.

remaining unchanged. In the corresponding terms, the orders of differentiation disappear, as does the time variable, and a new symbol appears written variously as $F(p)$, $F(s)$, $L(p)$, p, s, etc. The transformed terms lend themselves readily to algebraic manipulation enabling the transform of θ to be expressed in terms of the original constants and the new symbol. This resultant equation can be anti-transformed, by reference to the table, giving θ in terms of the known constants, the time variable and the initial conditions.

The procedure will be illustrated by the development of Equation (15): $d\theta/dt - \theta/L = X_0 . w . \cos(wt)$.

The sign $\subset$ means transforms into, and the reverse sign $\subset$ means reconstitutes to. The constants remain unchanged as multipliers.

Reference to a table of Laplace transforms gives:

$d\theta/dt \subset \bar{\theta}\, p - \theta_0$ where $\bar{\theta}$ is the transform of θ;
θ_0 is the value of θ at $t = 0$;
$\theta \subset \bar{\theta}$ p is the new symbol introduced.

$$\cos wt \subset \frac{p}{p^2 + w^2}$$

$$\sin wt \subset \frac{w}{p^2 + w^2} \qquad e^{at} \subset \frac{1}{p + a}$$

Transforming both sides of Equation (16) we obtain:

$$\bar{\theta}\, p - \theta_0 - \bar{\theta}/L = X_0 \frac{wp}{p^2 + w^2}$$

Rearranging:

$$\bar{\theta} = \frac{1}{(p - 1/L)} \left(\frac{X_0\, wp}{p^2 + w^2} + \theta_0 \right) \qquad \ldots . (18)$$

It is seen that in this transformed equation, t and all differential forms have gone, and the new symbol p has appeared.

This equation is put into a form giving terms which appear in the Laplace transform table. This is done by putting into partial fractions. Standard methods of doing this are available where this cannot be done by inspection. Equation (18) resolves to:

$$\bar{\theta} = \frac{1}{(p - 1/L)} \frac{(X_0\, wp + \theta_0 p^2 + \theta_0 w^2)}{p^2 + w^2}$$

$$= \frac{\left(\theta_0 - \dfrac{X_0\, wL}{1 + w^2L^2}\right)}{(p - 1/L)} + \frac{X_0\, wL}{1 + w^2L^2} \left(\frac{p}{p^2 + w^2} + \frac{w^2L^2}{p^2 + w^2} \right) \qquad \ldots . (19)$$

Reference to the Laplace transforms given earlier shows how this equation is now reconstituted in terms of the variable t. The term $\dfrac{1}{p - 1/L}$ is of the form $\dfrac{1}{p + a}$ which is the transform of e^{at}. Putting $-1/L$ for a, it is found that $\dfrac{1}{p - 1/L}$ is the transform of $e^{-t/L}$.

As stated, the constants in the equation are simply multiplying factors, so Equation (19) becomes by the inverse transformation:

$$\theta = \left(\theta_0 - \frac{X_0\, wL}{1 + w^2L^2}\right) e^{-t/L} + \frac{X_0\, wL}{1 + w^2L^2} [\cos(wt) + wL \sin(wt)] \qquad \ldots . (20)$$

The following trigonometrical manipulation links Equation (20) with Equation (16).

Substituting $\dfrac{\cos A}{\sin A}$ for wL

$$\cos(wt) + wL \sin(wt) = \frac{\cos(wt) \sin A + \sin(wt) \cos A}{\sin A} = \frac{\sin(wt + A)}{\sin A}$$

$$= (1 + w^2L^2)^{\frac{1}{2}} \sin\left(wt + \tan^{-1} \frac{1}{wL}\right)$$

since $wL = \cos A/\sin A$; $w^2L^2 = \dfrac{\cos^2 A}{\sin^2 A} = \dfrac{1 - \sin^2 A}{\sin^2 A}$

whence $\sin^2 A = (1 + w^2L^2)^{-1}$

and $\dfrac{\sin A}{\cos A} = \tan A = 1/wL$, whence $A = \tan^{-1} \dfrac{1}{wL}$.

The whole of this derivation has been effected without any reference to the significance of p or the underlying theory, just as logarithms can be used without referring to the exponential theory.

The Thermometer Response Equation

Equation (20) is in a suitable form for deriving a more useful expression for T_1 from Equation (17).

$$T' = T_m + X_0 \sin(wt) - \theta$$

$$= T_m + X_0 \sin(wt) - \left(\theta_0 - \frac{X_0\, wL}{1 + w^2L^2}\right) e^{-t/L} - \frac{X_0\, wL}{1 + w^2L^2} [\cos(wt) + wL \sin(wt)]$$

$$= T_m - \left(\theta_0 - \frac{X_0\, wL}{1 + w^2L^2}\right) e^{-t/L} + \frac{X_0}{1 + w^2L^2} [\sin(wt) - wL \cos(wt)]$$

which by the method just described, reduces to

$$T' = T_m - \left(\theta_0 - \frac{X_0\, wL}{1 + w^2L^2}\right) e^{-t/L} + \frac{X_0}{(1 + w^2L^2)^{\frac{1}{2}}} \sin(wt - \tan^{-1} wL) \qquad \ldots . (21)$$

Example 11

Solve Example 10 using Equation (21) and explain the significance of the multiplier $\dfrac{1}{(1 + w^2L^2)^{\frac{1}{2}}}$ and $\tan^{-1}(wL)$.

As before, the exponential term giving the transient response drops out. Substituting the numerical values for the constants, we have

$$T' = 200 + \frac{10}{1.68} \sin(3t - \tan^{-1} 1.35)$$

$$\simeq 200 + 6 \sin(3t - 53°)$$

T' is a maximum when $\sin(3t - 53°)$ is $+1$, and is a minimum when $\sin(3t - 53°)$ is -1, and therefore $T' \simeq 206°F$ max. or $194°F$ min.

Sin $3t$ and hence T (the water temperature) is at a maximum when $3t = n.360 + 90°$, whereas $\sin(3t - 53°)$ and hence T' is a maximum when $3t - 53° = n.360 + 90°$, i.e., $3t = (n.360 + 90°) + 53°$.

The maxima (and likewise the minima) of T' therefore occur $53°$ later than those of T, which confirms the result of Example 10. $\text{Tan}^{-1}\, wL$ is then the phase lag of T' behind T.

The multiplier $\dfrac{1}{(1 + w^2L^2)^{\frac{1}{2}}}$, or 0.6, is the factor which reduces the amplitude of the temperature swing. The amplitude of T is X_0 or $10°F$, while the amplitude of T' is $6°$.

If temperatures are measured from the mean water temperature, $T_m = 0$, then Equation (21) reduces to

$$T' = \frac{X_0}{(1 + w^2L^2)^{\frac{1}{2}}} \sin(wt - \tan^{-1} wL) \qquad \ldots . (22)$$

which is written as

$$T' = \frac{X_0}{\alpha} \sin(wt - \varphi) \qquad \ldots . (23)$$

This form of equation is common in process control. α is the attenuation and φ the phase lag.

ADVANCES IN THE PURIFICATION OF INERT GASES

Results of research conducted in Russia on the use of activated copper granules for the removal of oxygen from the crude gases

A NEW method for the removal of oxygen from crude argon or other inert gas, which makes use of activated copper, has been described by N. S. Torochesnikov and co-workers (*Khim. Promyshl.*, 1956, **4**, 32-38). It is claimed to be an improvement on previous methods, and with a "modified" copper bed, for example, a small-scale plant reduced the oxygen content of crude argon to indetectable traces after 28 to 30 minutes, with an hourly input of 30 to 35 n. cu. m.

The process depends on the oxidation of copper and the reduction of the resulting copper oxide with reducing gases. Processing problems include the need to remove the heat of the reactions, and one of the aims of the authors was to make the process auto-thermal. Furthermore, the activity of the copper surface has to be maintained over repeated oxidation and reduction cycles, and the process must also be economical and practical for industrial use. Suitable reducing agents were found to be coke-oven gas or various reducing gases mixed with it. From free energy considerations, the most suitable reducing agent appeared to be carbon monoxide, although hydrogen, too, was potentially satisfactory. The author concludes from his practical work that: (1) It is better to use a thick layer of activated copper granules, as this results in more uniform heating and to some extent prevents local overheating. The depth of the bed also helps to preserve the copper granules during the reduction process. (2) Carbon monoxide produces an almost complete reduction of the oxidised copper; and (3) mixed gas is superior to hydrogen alone.

Among the laboratory work carried out was a determination of the effect of repeated oxidation and reduction on the activity of a copper surface and the effect of variation of the oxygen concentration in the gas to be purified, the maximum limit being 40%. It was found that the initial temperature of oxidation varied from 230°-240°C, and reduction was best carried out in the temperature range 270-280°C. Temperatures in excess of 550°C in either stage of the process must be avoided. Fig. 1 shows the relation between the number of oxidation-reduction cycles for oxygen contents of 20% and 40% in the gas to be purified, and the activity of the copper. The activity falls sharply during the first four or five cycles and then remains practically constant at a level of 4.7% of copper in the oxygen mass for an indefinite number of cycles. At the pilot-plant stage, modifications made to the laboratory design included the addition of further reactors, one for the oxidation of copper and one for reduction. Changeover from regeneration to reaction is carried out automatically every 20-40 minutes (the time cycle is in inverse ratio to the volumetric throughput) and it is therefore possible to use relatively small reactors.

In a small production unit a heat exchanger replaces the preheater for securing a more uniform temperature distribution throughout the copper mass. Purified carbon monoxide or other reducing gas is introduced into the plant, the hot gas from the reactor exit being fed to the heat exchanger where it is cooled down to 280 to 300°C, and it warms the incoming gas to the temperature required by the reaction. The method of the operation is as follows: Crude argon at 2 atm. pressure is fed into the bubbler (6), it is then raised to 100°C, is mixed with steam and passes into a heat exchanger (7) where it is raised in temperature to 300°C. It then passes to the upper half of a reactor (8) where the main part of the oxygen content is removed; the temperature rises to 550-600°C because the oxidation reaction is exothermic. The treated gas and steam mixture now enters the heat exchanger (7) where it is cooled to about 300°C, and it is then fed into the lower half of the reactor (8) for final purification. At this stage the argon in the mixture can be looked upon as technical argon. The purified gas is then passed through a cooler condenser in which the water is separated from the main argon steam. While the purifying process is proceeding in one reactor, regeneration of the oxidised copper is proceeding in the other. The reducing gas enters the reactor containing exhausted copper through a reducing valve (2) which serves to reduce the pressure to 1.5 atm. It is metered through a control system (5) (K-1 to K-3). The flow of reducing gas is downwards through the copper

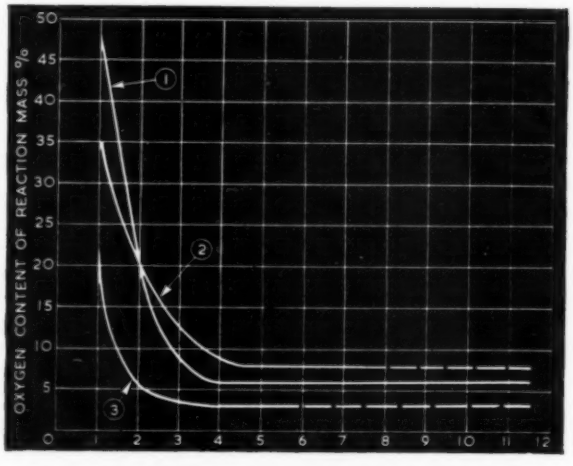


Fig. 1. The abscissa shows the number of cycles. Curve 1 is 20% O_2 (diluted with nitrogen), curve 2 is 20% O_2 (diluted with water vapour) and curve 3 is 40% O_2.

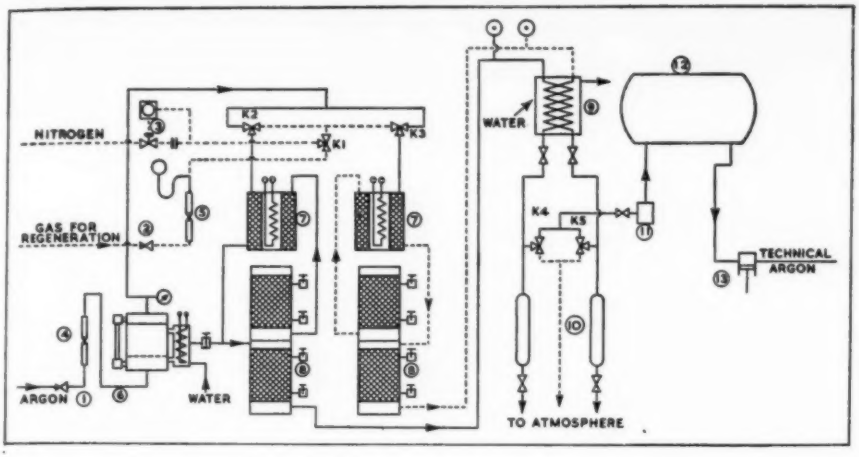


Fig. 2. Flow diagram of a small-scale production unit for purifying argon. Key: (1) and (2) reducing valves; (3) flow control valve; (4) and (5) rotameters; (6) bubbler; (7) heat exchangers; (8) reactors; (9) cooler; (10) entrainment collectors; (11) automatic gas analyser; (12) storage vessel; and (13) compressor.

bed (to avoid disturbing the bed) and is then directed into a cooler (9), an entrainment separator (10), and thence to atmosphere (see Fig. 2).

The change-over of reactors is carried out at 30-minute intervals. To prevent contamination of the argon by the remnants of the reducing gas in the regenerated reactor, a purge of nitrogen is applied to each reactor for one or two minutes before switching-in for purification duty. The nitrogen is introduced by the valve system K-1, K-2, K-3 and the quantity required is determined by a controller (3). The switching-in valves are operated by cam.

The following are typical compositions of crude argon refined at this plant: 10-14% oxygen, 6-8% nitrogen, 78-84% argon. Based on crude argon alone, the capacity of the small-scale plant was of the order of 40 n. cu. m. The composition of the reducing gas was 38.7% CH_4, 17.7% H_2, 9.5% CO, 2.6% CO_2, 18.5% N_2, 0.6% O_2 and 12.4% heavy hydrocarbons. The composition of this gas was at the rate of 0.8 n. cu. m. per 1 n. cu. m. of crude argon. The completion of the reducing process is indicated by the carbon dioxide content in the gases leaving the reactor during the regeneration cycle.

Experience of the small-scale plant has shown that it is necessary to charge the purifying reactor with material of uniform grain size. This measure helps to avoid channelling at the walls of the reactor through shrinkage of the grains. The same effects of falling-off activity noted during the laboratory-scale work were experienced on the pilot-scale plant, as was the constancy after the falling-off. The normal cycle for granulated copper beds was about 25-26 minutes and the amount of oxidation of the copper did not exceed 4%.

Attempts have been made to improve performance of the copper packing by using it in conjunction with iron turnings or chippings. Torocheshnikov demonstrates that a somewhat higher activity is conferred upon copper and that a more uniform temperature distribution is obtained. Actually the CO_2 content in the reducing gas can be as high as 27%, with a maximum temperature limit not in excess of 600°C. It has also been established that the copper is more effective if prepared by reduction from cupric oxide. The performance of the pilot-scale plant using the modified copper bed referred to was obtained with a bed of 0.125 n. cu. m. volume and a depth of 1.3 m., and a space velocity of 240-280 n. cu. m. an hour per cu. m. of reaction mass. The weight of the copper was 300 kg. and the iron turnings 16 kg. and the grain size of the copper, which was in either grains or tablets, was 10 mm. diameter or cube. The percentage oxidation of the copper was raised to 4.3%. Reactor pressures were 2 atm. for the argon-purification process and 1.5 atm. for the reducing gas.

The author concludes with a description of a plant for the separation of both technical and pure argon from air (Fig 3). It consists essentially of the activated copper plant added to a normal gas-separation air-distillation plant. The air is subjected to double rectification and the argon obtained from a side stream from the copper column undergoes supplementary rectification. After passing through a heat exchanger, it is pumped by a compressor to the purification plant. Here the initial stage is its humidification in readiness for the various oxidations and reductions. The gas stream then follows one or other path according to whether a technical or greater purity grade is required.

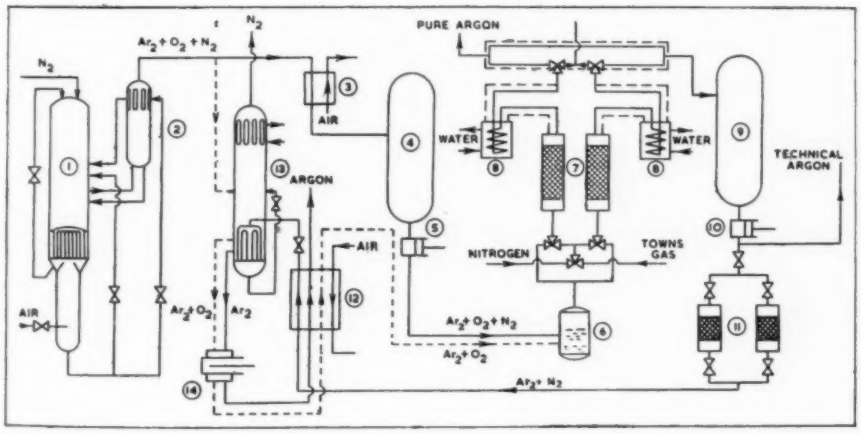


Fig. 3. Flow diagram of full-scale plant for producing pure and "technical" argon. Key: (1) double column; (2) argon side column; (3) and (12) heat exchangers; (4) gas-holder for crude argon; (5) and (10) compressors; (6) humidifier; (7) reactors; (8) coolers; (9) gas-holder for "technical" argon; (11) absorption driers; (13); argon purification column; and (14) liquid argon pump.

PACKED DISTILLATION COLUMNS

One of the main disadvantages of packed columns, especially the large ones, is the wall effect. How the performance of packed columns is influenced by column diameter and wall effect, and how this performance may be improved by replacing the smooth wall of the vessel by a corrugated one are described in this article

by Dr. E. KIRSCHBAUM*

THE efficiency and the loading of two packed columns of diameter 750 mm and 400 mm respectively were studied under identical conditions. In both cases, an ethanol/water mixture was used, and the columns were packed with porcelain rings of diameter 23 mm to a depth of 1 m. A specially-designed distributor was used in the large column to ensure even distribution of the reflux over the column cross-section.

The columns were operated under total reflux, and the vapour velocity referred to the free cross-section of the column was taken as a measure of the loading. When the system reached a steady state, samples were taken at suitable points to enable the achieved number of theoretical plates n_t to be determined, this quantity being taken as a measure of the column efficiency. In taking these samples, allowance was made for the variation in liquid composition over the column cross-section.

The achieved number of theoretical plates was then plotted as a function of the vapour velocity to give the loading curves for the two columns (see Fig. 1). These curves show that, with a decrease of column diameter from 750 mm to 400 mm, the maximum permissible vapour velocity increases from 0.75 m/sec. to 1 m/sec., while the corresponding number of theoretical plates increases from 5.75 to 6.1. This result is surprising as the ratio of column diameter to ring size is greater in the large column.

Apparently in the large column there are more opportunities for the uneven flow of both phases across the column cross-section. The correctness of this supposition was confirmed by measurements of the composition of the reflux below the packing support grid of the large column. The difference between the alcohol content of the liquid at the wall, x_a, and that at the centre of the column, x_i, was plotted against the vapour velocity, as shown in Fig. 2. For velocities up to 0.8 m/sec., this difference was negative, i.e., the alcohol concentration at the centre of the column was higher than that at the wall. For velocities greater than this figure, the difference was found to be positive. A similar effect was found when rings of diameter 50 mm were used (see Fig. 2).

An important reason for this peculiar behaviour lies in

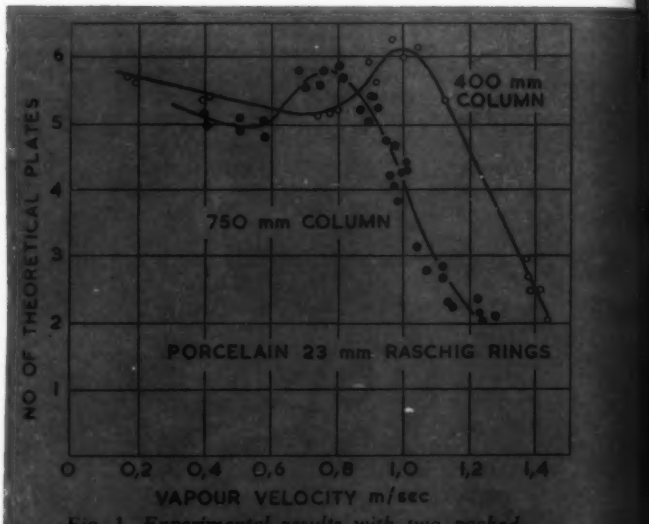
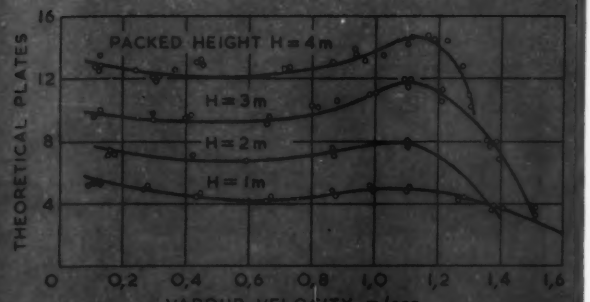
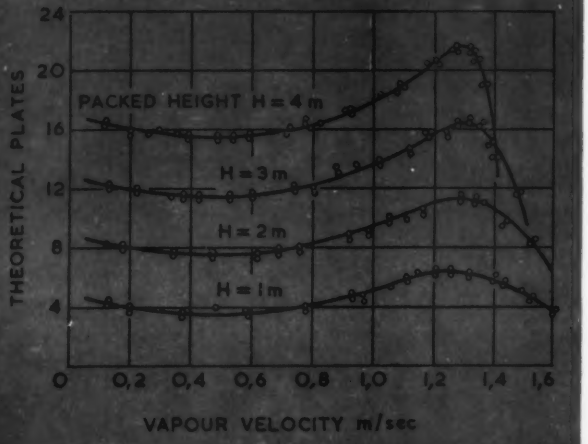


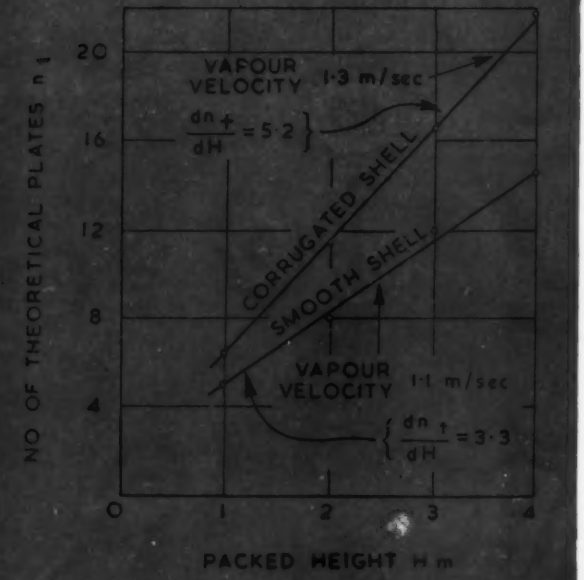
Fig. 1. Experimental results with two packed columns showing the variation of the number of theoretical plates with vapour velocity.

Fig. 2. Curves showing variation in the concentration difference between liquor at the wall and in the column, for different packing sizes

* The above is a prepared translation by J. Jackson, B.Sc., and is an abstract from the author's original work which appeared in *Chem.-Ing.Tech.*, 1956, **28**, (10), 639.







Relationship between the vapour velocity at loading and the number of theoretical plates achieved for different depths of packing for (top) smooth-walled columns (Fig. 3) and for a corrugated-walled column (Fig. 4).

Fig. 5 (bottom). Comparison of performances of smooth- and corrugated-walled columns at maximum permissible vapour velocity.

the fact that the packing rings do not have the same arrangement near the wall as at the centre of the column. This factor clearly affects the vapour flow even at packed depths of only 1 m. For packed depths greater than this, the difference in the performance of packed columns of different diameter would presumably be even greater than that shown by Fig. 1. Because of the special arrangement of the rings at the column wall, the vapour velocity near the wall will be much greater than that at some distance from it. This wall effect will also influence the liquid flow at great packed depths.

Wall Effect for Greater Packed Depths

The wall effect was studied, not only by using greater packed depths, but also by working with two columns, one of which was fitted with the normal smooth column shell and the other with a corrugated shell specially designed to avoid giving rise to this effect. The minimum inside diameter of the corrugated shell was 400 mm, i.e., the same as that of the smaller of the two columns used in the previous work. Results were obtained for packed depths of 1, 2, 3 and 4 m, both columns being packed with rings of diameter 28 mm. The loading curves, which show the relation between the vapour velocity and the achieved number of theoretical plates, were plotted as before for the various packed depths (see Figs. 3 and 4). These show the rate of vapour velocity to the number of theoretical plates.

For the column with the smooth wall, all the loading curves show a maximum value of the achieved number of theoretical plates corresponding to a vapour velocity of 1.1 m/sec. (see Fig. 3). The effect of corrugating the column shell is shown by the curves given in Fig. 4, which indicate a maximum permissible loading corresponding to a vapour velocity of 1.3 m/sec.; the number of theoretical plates achieved for a packed depth of 4 m is then 21.8, as opposed to 14.6 for the column with the smooth shell. The effect can be seen more clearly if the achieved number of theoretical plates corresponding to the maximum permissible vapour velocity is plotted against the packed depth, as shown in Fig. 5. For packed depths greater than 1 m, the relation between these two quantities is a straight line, the slope of which is equal to the number of theoretical plates in unit packed depth. For the smooth shell, this slope has the value 3.3, and for the corrugated shell 5.2, i.e., an increase of 58%, in spite of the greater loading. For a packed depth of 1 m, the corrugation only brings about an increase from 5 to 6.5 in the maximum number of theoretical plates, i.e., an increase of 30%. The improvement effected by the corrugation is thus greater as the packed depth increases.

It may seem surprising that the curves showing the relation between the number of theoretical plates and the packed depth should be straight lines. It must be remembered, however, that the vapour also shows a wall effect (see Pressure-drop and Loading Limits in Packed Columns, by Mach, E., *VDI-Forsch.-Heft* 375, Berlin, 1935) and this can outweigh that of the liquid.

The differences in the effectiveness of separation of the columns with corrugated and smooth column shells are very large. The reasons for such differences must lie in the dependence of the flow phenomena on the manner in which the packing rings arrange themselves at the wall. It can be demonstrated very clearly by means of a glass-walled column that the rings normally arrange themselves so that their axes are either vertical or parallel to the wall surface. There is therefore an absence of inclined surfaces which could lead the vapour and liquid away from the wall. The rings can be induced to arrange themselves so as to provide these inclined surfaces by means of the corrugated shell.

SCALING UP OF PLANT AND PROCESSES

Abstracts of selected papers given at the joint symposium which was held in London recently by the Institution of Chemical Engineers, the Society of Chemical Industry, Het Koninklijk Instituut van Ingenieurs, and De Koninklijke Nederlandse Chemische Vereninging are published below*

SCALE-UP METHODS FOR CONTINUOUS FILTRATION EQUIPMENT

by D. A. Dahlstrom,† B.Sc., Ch.E., Ph.D., and D. B. Purchas,‡ B.Sc., A.M.I.Chem.E.

THE SIZE OF a filter for any duty will be decided by the slowest of the various time-consuming parts of the filtration cycle, such as filter-cake formation, dewatering, washing or thermal drying. For scale-up purposes, each part must be investigated.

By integrating the modified Poiseuille equation, the filtration rate expressed in volume of filtrate per unit area per unit time may be written:

$$\frac{V_f}{A\theta_c} = Y = \left[\frac{2\,(\Delta p)^{1-s}\,B}{\mu\ \alpha\ w\ \theta_c}\right]^{\frac{1}{2}} \qquad \ldots.(4)$$

which shows how the variables may affect rate of filtration. From this expression, a plot on logarithmic co-ordinates of Y as a function of θ_c or θ_f should give a straight line of slope -0.5. At a constant cycle time (θ_c), the filtration rate is directly proportional to $\sqrt{B}$; hence a similar plot should have a slope of $+0.5$.

Generally, straight lines are obtained, but the slopes are not always ± 0.5, since the specific cake resistance, α, may change during the filtration. For example, for malamine crystals in aqueous ammonia, the Equation (4) becomes:

$$Y = 56.0\ (\theta_c\ B)^{-0.617} \qquad \ldots.(5)$$

For a cycle fraction of 0.25 and allowing a scale-up factor of 0.8, this reduces to:

$$Y = 105.3\ (\theta_c)^{-0.617} \qquad \ldots.(6)$$

Equation (4) suggests that cake filtration rate is proportional to $\sqrt{w}$, but this is not a safe assumption, because s often decreases with an increase in w. It is safer to investigate the effect of cake compressibility experimentally. It also predicts that filtration rate is proportional to $\Delta p^{(1-s)/2}$, so that with $s = 0$, or $s = 1$, corresponding to incompressible and compressible cakes, the rate is proportional either to $\Delta p^{\frac{1}{2}}$ or independent of the pressure drop. In practice, most materials lie between these two extremes. Nevertheless, from filtration rate and pressure drop data, relationships similar to Equation (6) may be obtained which are useful in determinining the most economical installation in a particular case.

The dewatering process is physically complex and, at present, empirical methods are used for scaling up.

The variable factors affecting final cake moisture are:

(1) cake dewatering time;

(2) pressure drop, both during cake formation and cake dewatering;

(3) gas flow-rate through the cake;

(4) filtrate viscosity (which is sensitive to temperature changes); and

(5) cake thickness.

Other factors, such as specific permeability, concentration of solids in slurry, particle-size distribution and type of filter, also influence the cake moisture but these may be constant or, if variable, treated as parameters.

For the variable, the correlating factor is given by:

$$\Delta p \left(\frac{\theta_D}{D}\right)\left(\frac{CFM}{A}\right)\left(\frac{1}{\mu}\right) \qquad \ldots.(7)$$

The plot of the final cake-moisture content v. the correlating factor gives a smooth curve with a distinct point of inflexion. The plant design is then based upon a value of this factor to the right of this point of inflexion.

The filtration rate can be readily calculated from the cake thickness D, itself a measure of weight of solids discharge per unit area per cycle, and the drying time, θ_D, divided by the fraction of cycle available for drying. A scale-up factor of 0.8 should be applied to the value thus obtained.

The size of vacuum pump or compressor is determined by the pressure drop, Δp, and the gas-flow rate per unit area. The product of these two factors can be calculated from the correlating factor, but if they are required separately, then curves must be plotted with cake thickness as parameters and with air flow and pressure drop as ordinate and abscissa respectively.

The cake-washing rate is determined by the quantity of wash liquor required and the rate at which it can flow through the cake.

Assuming a diffusional mechanism, one can determine the former from:

$$R = (1 - E/100)^n \qquad \ldots.(8)$$

In practice, diffusion may not always control but, nevertheless, the law may still be safely used. The practice here is to plot on semi-log paper the work ratio against concentration of solids in cake.

The flow rate of wash liquor may be obtained from:

$$\theta_w = K'\,\theta/fn \qquad \ldots.(10)$$

which is the basis for a linear graph of washed time v. wash ratio with form time as parameters. It is then possible to estimate the full-scale filtration rate as a function of wash ratio by using Equation (4) and the latter curve, using, as previously, a scale-up factor of 0.8.

Cakes of relatively coarse solids such as ammonium sulphate can be dried by drawing hot gas through them. The filters for such solids have generally top feed, and it is noteworthy that, when the method is applicable, the combined costs are lower than with a separate filter and drier.

Cake thickness is usually $\frac{1}{2}$ in. to 1 in. and drum speeds $1\frac{1}{2}$-$2\frac{1}{2}$ mpr. For scaling up, a procedure is described wherein the dewatered moisture content of a cake is found for different thicknesses of cake. The log mean value of the flow of air entering and leaving the cake is then determined for values in the range 3-6 in. Hg. The first of these two graphs gives the amount of moisture to be removed and permits a heat balance to be carried out and hence the quantity of air required. From the second graph the cake-thickness value selected gives the rate of flow at different vacua, and therefore permits calculation of the filtration time.

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* *Other abstracts of selected papers read at the symposium were published in the July issue, pp. 374 to 377.*

† *The Eimco Corporation.*

‡ *L. H. Manderstam & Partners Ltd.*

Discussion

DR. F. SZENITZER (Bataafsche Petroleum, D.O. Department) had four points to discuss on DR. DAHLSTROM'S paper. Filter-cloth resistance was assumed to be negligible, although the authors were aware that this was not the case. The resistance of the filter cloth could be included in the equation given in the paper:

$$V_f/A = \left[\frac{2\,(\Delta p)^{(1-s)}\,\theta_f}{\mu\,\alpha'\,w}\right]^{\frac{1}{2}} \qquad \ldots.(3)$$

in which case to give:

$$\frac{V_f}{A} = \frac{r}{AW} + \sqrt{\frac{r^2}{\alpha^2 w^2} + \frac{2\,(\Delta p)^{1-s}\,\theta_f}{\mu\,\alpha'\,w}} \qquad \ldots.(3a)$$

which reduces to Equation (3) when r is very small.

Dealing with the treatment of cake filtration rate, he had found that the resistance of the cake when the filter cloth was negligible was given by:

$$P = \sqrt{\frac{C.H}{1-\varepsilon-c}} \qquad \ldots.(28)$$

where P was the cake rate, H a constant, c the volumetric concentration of solids in slurry feed and the volumetric porosity of the cake, which gave a curve which, unlike that of the authors', passed through the origin of the plot of cake filtration rate v. feed solids concentration. It checked well with the authors' observations.

His third point concerned cake dewatering rate. The correlating factor had the dimensions of reciprocal time and he had found a slightly different equation:

$$\frac{DA}{\theta_D\,CFM} = F\left(\frac{\Delta p\;\theta_D}{\mu}\right)$$

which gave a satisfactory correlation. Washing efficiency was the subject of his final point. From his experience, he could state that the washing efficiency, E, for the diffusional washing step lay between the limits of 35-86% given by the authors.

Symbols Used

A = area;
B = fraction of cycle devoted to cake formation;
D = cake thickness;
E = wash efficiency % $= (1 - R)\ 100$ at $n = 1.0$;
K, K' = proportionality constants;
n = wash ratio,
$= \dfrac{\text{volume of wash fluid}}{\text{unit volume of liquor in cake prior to wash}}$;
R = weight fraction of dissolved salt or strong liquor remaining in the cake after washing on the basis of $R = 1.0$ prior to washing (i.e., if no washing is performed, $R = 1.0$);
s = cake compressibility exponent on Δp ranging from 0.0 for non-compressible cakes to 1.0 for highly-compressible cakes;
V_f = volume of filtrate at θ_f;
w = weight of dry cake solids per unit volume of filtrate;
CFM = standard cu. ft of gas per min., measured at atmospheric pressure and 60°F;
α = specific cake resistance;
α' = specific cake resistance at $\Delta p = 1.0$ (derived from $\alpha = \alpha'\,(\Delta p)^s$);
Δp = pressure drop across filter;
θ = time;
θ_D = cake dewatering time;
θ_f = cake formation time;
θ_w = cake washing time; and
μ = filtrate absolute viscosity.

REMOVAL OF HYDROGEN SULPHIDE

by M. J. Hagger, B.Sc., A.M.I.Chem.E., E. A. Jones,* B.Sc., and D. C. F. Pratt,* A.C.G.I., A.M.I.Chem.E.*

THIS PAPER OUTLINED the design of a plant for removing CS_2 and H_2S from the atmosphere discharged from certain regions of a viscose factory. The full-scale plant was to handle something like 280,000 cfm of air containing 800-1000 ppm CS_2 and 300 ppm H_2S together with smaller amounts of other compounds. The final H_2S content of the air leaving the treatment plant had to be no higher than 10-20 ppm.

The process adopted utilises the absorptive capacity of alkaline solution for H_2S followed by regeneration of the solution by catalytic oxidation. Gas-film coefficients (the gas film is controlling in the absorption process) obtained with the laboratory falling-film column were of the order of 0.35-0.45 lb./hr sq. ft atm. using various alkaline solutions of approximately 0.047-0.056 molar concentration. A study of the oxidation reaction for absorbent regenerating was also studied closely in the laboratory. The conclusions drawn for this stage of the work were that the requirements for good absorption were a large liquor surface per unit volume, high alkalinity (preferably N_2OH) and low concentration of dissolved salts, whereas the conditions for economic regeneration were low alkalinity, low degree of aeration, high catalyst core and high oxygen-transfer rate.

This work enabled the authors to construct a pilot plant. The 2-ft square-sectioned absorber had a 10-ft depth of glass-plate packing which did not give the desired degree of H_2S removal; the tower was therefore converted to a spray column. One advantage of this alteration was a reduced pressure loss. Another interesting feature of the pilot plant was the substitution of canvas sleeves for the more conventional sparger in the regenerating tank.

Among the conditions for the successful operation of the process revealed by the pilot plant were that catalyst concentration should not fall below 1% and that a good air velocity be maintained up the column. Tank size and catalyst concentrations were also found to be interdependent and had to be fixed to give a negligible NaHS concentration at the sprays, which had to be numerous in order to handle the large volume of liquor required by the process. For this reason, and also because the droplets are most effective a few feet from the jets, the latter were arranged evenly throughout the tower volume.

In prototype design, the following points had to be determined:

(1) the volume of the chamber;
(2) the shape of the chamber;
(3) the liquor circulation rate and spraying pressure;
(4) the geometrical positioning of the jets;
(5) the type and size of the jets; and
(6) the size and shape of the regeneration tank.

Two absorption coefficients were used; these were the volumetric absorption coefficient

$$K_1 = \frac{\text{lb. mol. } H_2S \text{ removed}}{\text{hr. cu. ft} \times \text{log mean conc. of } H_2S \text{ in atmospheres}}$$

This varies with such factors as the type of jet, higher circulation rate and shape of tower.

Another coefficient was devised:

$$K_2 = \frac{\text{lb. mol. } H_2S \text{ removed}}{\text{(gal. liquor)} \times \text{log mean conc. } H_2S \text{ atmospheres}}$$

Although the log mean driving force is not strictly valid, it was thought to be a fair approximation for the pilot plant. On the full-scale plant it seemed likely that the actual driving force would be lower than that represented by the log mean.

* *Courtaulds Ltd.*

The volume of the full-scale limit was calculated from the coefficient K_1 obtained from the pilot plant. The flow per unit tower volume was calculated from pilot-plant values of K_1 and K_2 and the jets were arranged in twelve horizontal layers through the column. The dimensions of the regeneration tank were obtained by scaling up the minimum volume from pilot-plant experience, and the total area of the aerator sleeves was scaled up in proportion to the throughputs. This unit proved capable of reducing the H_2S conc. from 300 ppm to 20-30 ppm. (10-20 ppm was the aim of the designer.)

The cost of liquor circulation was the major expense with this unit, and the desire to design a plant with a cheaper circulation system led to the later horizontal unit, whose dimensions were also determined by the use of K_1 and K_2 values. An interesting feature of this unit is the installation of spray nozzles at ground level, arranged to spray the liquor upwards at an angle of 45 degrees. These nozzles proved capable of reducing the H_2S conc. to 13 ppm, and figures as low as 5-10 ppm were obtained with liquor rates above the normal 5-10 ppm. The air throughput in this unit was 125,000 cfm at a velocity of 5.9 ft/sec., while liquor was distributed through 140 jets. Grids were installed to promote stagewise absorption.

Discussion

MR. L. L. KATAN (Shell Refining Co. Ltd.) commended the authors for having the courage to state at the beginning of their paper that it was not an example of academic scale-up principles, but rather a demonstration of how scaling up is often carried out. One of the questions posed by Mr. Katan was whether a "cave" absorption column might not be adapted for a forced-draught cooling-water system. Another thing he wished to know was the reason for discarding the sloping plate-glass packing in the pilot plant.

In their reply, the authors stated that the reason for discarding the packing was its tendency to foul. It had to be appreciated that the column liquor was an iron oxide slurry and sulphur would precipitate from the solution as well. The advantages of the horizontal chamber were lower capital and running costs. They had used it for acetone absorption and they saw no reason why it might not be applied for forced-draught cooling towers. In reply to questions from DR. KHARBANDA (Costain-John Brown Ltd.) regarding materials of construction, MR. PRATT said that most of the pilot plant was constructed of bitumen-lined mild steel; 18/8 stainless steel was used only for items like filter screens and eliminator plates.

The H_2S analysis which had given a great deal of trouble through sampling difficulties at all stages of the work—they had found it necessary to use duplicate sampling lines—might in the future be carried out continuously.

GENERAL CONSIDERATIONS

by R. Edgeworth Johnstone and Prof. M. W. Thring†*

WHAT IS NEEDED today in the field of model theory applied to chemical engineering are more data on the actual performance of small- and large-scale equipment under corresponding conditions, so that a better appreciation can be reached of the degree of accuracy to be expected from the application of scale-up principles and rules. It would, for example, be a useful exercise for students to construct a model or model element of a piece of operating plant, test it under appropriate conditions and compare the predicted and actual performance of the prototype.

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† *University of Sheffield.*

A second requirement is for some improvement on the empirical power-function relationship between dimensionless groups. The customary empirical exponents vary considerably according to conditions; for example, in equations for heat transfer by forced convection, the exponent on the Reynolds number may vary from 0.5 to 0.8 according to the geometry of the system. A less empirical form of function would allow of more accurate and reliable extrapolation. Improvements along either of these lines would enable more information to be obtained in less time from smaller and cheaper models or pilot plants. As theoretical knowledge of chemical engineering increases, it is possible that the pilot-plant stage in process development may come to be omitted more often; yet ultimately it is a question of balancing the costs of pilot-scale development against higher capital costs and more prolonged teething troubles on the main plant when the pilot stage is by-passed. The greater the economies that can be made in small-scale experimentation by the application of model theory, the more frequently will it be advantageous to build and test a pilot plant. In any case, whether the construction of a pilot plant is envisaged or not, a theoretical scale-up study of a new process can often enable subsequent operating difficulties to be avoided.

Where the form of an equation governing a physical or chemical process is entirely unknown, the appropriate dimensionless groups can, in theory, be derived by dimensional analysis using either Rayleigh's method of indices or Bridgman's method of matrices—always assuming that all the physical variables which significantly affect the process are known. There is another and, in the authors' view, a better way of deriving dimensionless groups. For nearly all the physical and chemical processes of interest to chemical engineers the fundamental differential equations are known, although in many cases they cannot be integrated. Provided these differential equations are dimensionally homogeneous (as all complete physical equations should be), they can be simplified to a generalised dimensional form by dropping the differential signs and substituting for linear co-ordinates a generalised linear dimension, L. Dividing across by one term then gives the relevant dimensionless groups. When dimensionless groups are thus derived from a complete set of differential equations there is no doubt as to whether the correct variables have been included.

The strict principle of similarity required geometrically similar systems to be compared at equal values of the appropriate dimensionless groups called similarity criteria. In the past this requirement has limited the application of the principle to chemical engineering plant, since, in many cases, it is either impracticable or impossible to achieve. To meet this difficulty the method of extrapolation has been proposed. It has been found empirically that the unspecified function of the generalised dimensionless equation can, in many cases, be quite well represented by a power function, e.g., for closed fluid-flow systems:

$$\frac{\Delta p}{\rho v^2} = \text{const.} \left(\frac{\rho v L}{\mu}\right)^x$$

where L = linear dimension; p = pressure; v = linear velocity parallel to y co-ordinate; x = exponent on Reynolds number in fluid friction; and ρ = density.

Whether or not the fundamental differential equations governing a process are known, it is essential to discover the rate-determining factor or régime of the process before any prediction can be made about the effects of change of scale. The three broad types of régime that are met with in chemical engineering are dynamic, thermal and chemical. The prevailing régime must not be confused with the nature of the process itself. For example, heat transfer by forced convection is a thermal process, yet it takes place under a dynamic régime because the rate of heat transfer

is a function of the fluid velocity. Natural convection, on the other hand, is a thermal process subject to a thermal régime, since here the rate-determining factor is the temperature difference. Sometimes there are two or more rate-determining processes, each of which scales up according to a different law. This constitutes what is called a mixed régime. No scale-up procedure is possible unless the effect of one of these dimensionless groups is either calculable or can be rendered negligible.

Discussion

There was criticism of the absence of reference to other methods of scaling up, such as by increasing the number of processing units, by selecting a piece of equipment more suitable for handling material on a large scale, or by altering the flow scheme. However, it was pointed out that the conference was intended only to deal with the type of scaling up employing models and the principles of dynamic similarity. A further omission was a treatment of distorted models, of which work on flow through packed beds was an example.

PROF. K. G. DENBIGH suggested that the practice of relating dimensionless groups in a given case—for example, the heat-transfer expression for turbulent flow by power functions—need not always be followed. Sometimes it might be better to represent the Reynolds number by a Bessel function.

EXPERIMENTS WITH FURNACE MODELS

by N. P. Bacon, B.Eng., Ph.D., A.M.Inst.F.*

IN METALLURGICAL FURNACES the flow pattern of the combustion gases has a distinct bearing upon their performance; consequently, models are now widely used in the glass and steel industries.

The similarity conditions for oil- and gas-fired open-hearth furnaces are defined for both water and air models. Since the temperatures in the open-hearth furnace vary widely, the temperature used in the model must depend upon the part of the furnace in which the investigator is interested and the model operated at a Reynolds number related to the temperature range.

With water models the criterion of similarity is equality of Reynolds number at furnace and model; moreover, gas-fired models are made geometrically similar to the full-scale counterparts. With air models of gas-fired furnaces, the Reynolds number is again the criterion of similarity, but since events occur much more rapidly in the model than in the prototype, the flow pattern is difficult to observe. One way of overcoming this difficulty is to use a tracer such as balsa dust.

The Reynolds number criterion, however, is not adequate in the case of air models of oil-fired furnaces, because the density of the fuel-steam mixture injected into such a furnace is much greater than that of the flame gases. To compensate for this difference, the model nozzle is made larger than that obtained by simple scaling down, i.e., a distorted model is used. In the case of water models of oil-fired furnaces, the nozzles are sized to give the same rate of production of momentum as is achieved in the full-scale plant. The model is then designed by scaling down from a hypothetical prototype in which the density of gases is assumed to be constant throughout.

For any equal density system, the nozzle-outlet diameter

$$A_{en} = \frac{M_n^2}{G.g.\rho_f} \qquad \ldots.(3)$$

The water model nozzle can be determined from

$$D_{em} = D_{ep} \,.\, L_m/L_p \qquad \ldots.(4)$$

The thrust of the model burner is independent of scale and depends only upon the viscosity and density of the fluids used. With air models, the equivalent size of nozzle as determined for the water nozzle has to be corrected, because the air leaving the model nozzle will differ in temperature and pressure from the surrounding air.

The nozzle area for air models may be obtained from

$$A_n = \frac{M_n}{P_a.g} \cdot \left[2\left(\frac{\gamma+1}{\gamma}\right) . R.g.T_i\right]^{\frac{1}{2}} - \frac{G}{P_a} \qquad \ldots.(8)$$

which for atmospheric conditions reduces to

$$A_n = 0.218.\ M_n \,.\, T_i^{\frac{1}{2}} - 0.0680\ G \qquad \ldots.(9)$$

The model nozzle is independent of the efficiency of the nozzle—a valuable practical advantage, since it means that the nozzle profile is unimportant.

From A_n, P_n may be estimated from the thrust equation for a convergent nozzle:

$$G = (P_n - P_a) \,.\, A_n + (M_n \,.\, V_n)/g \qquad \ldots.(6)$$

If the delivery pressure of air behind the nozzle is required, a nozzle efficiency of 90% may be used.

The limit to the value of burner thrust that can be simulated in a model is fixed by the air pressure developed at the compressor. If it becomes necessary to simulate conditions which require a greater thrust than can be achieved practicably, then the model must be run with a lower Reynolds number than the prototype or a larger model used. If the model Reynolds number is a fraction, S, of that in the furnace, the thrust required of the model is given by:

$$M_n = M_p \,.\, \left(\frac{L_m}{L_p}\right) \cdot \left(\frac{\mu_m}{\mu_p}\right) \qquad \ldots.(10)$$

In a model in which fuel is burnt to give the same temperature as in the prototype, the burner should have the same thrust. If this is not possible, the model must run with a reduced mass flow.

Symbols Used

A = area (sq. ft);
G = burner thrust (lb. wt.);
g = conversion factor, gravitational to absolute units (32.2 ft/sq. sec.);
L = characteristic length (ft);
M = mass flow rate (lb./sec);
P = pressure (lb. wt./sq. ft abs.);
R = gas constant (for air=96.05 ft lb/lb. °C);
S = N_{Rm}/N_{Rp};
T = temperature (°K);
γ = ratio of the specific heats C_p/C_v (for air=1.40);
μ = viscosity—absolute (lb./ft sec.); and
ρ = density (lb./cu. ft).

Subscripts

a refers to ambient conditions;
e refers to equal density system;
i refers to inlet conditions before the nozzle;
m refers to model;
n refers to conditions in the nozzle throat, and
p refers to prototype.

Discussion

PROFESSOR THRING (Sheffield University) said that Dr. Bacon had developed a theory for similarity, the equivalent nozzle-diameter theory, and he had the advantage over most chemical engineers in that his full-size plant was already in existence. He suggested that nozzle efficiency was best defined by the efficiency of momentum production—the relationship of momentum actually obtained to that achieved under ideal conditions—for jet momentum was the criterion of a good burner.

* *The United Steel Companies Ltd.*

NEW PLATFORMING UNIT AT ELLESMERE PORT

Lobitos, one of Great Britain's smaller but none-the-less comprehensive petroleum refineries, has recently increased its versatility by the construction and operation of a Platforming* unit

THE Platforming process used by Lobitos Oilfields Ltd. at Ellesmere Port is operated under licence from Universal Oil Products Co. The process itself has been extensively described in the literature,[1] and involves the reforming of a hydrocarbon oil fraction boiling within the motor spirit range by passing it at high temperature (450-520°C) and pressure (200-1000 psi) over a platinum catalyst on a suitable carrier. The main net reaction is aromatisation consequent upon the dehydrogenation of naphthenes; there is also a certain amount of isomerisation, which increases the iso-paraffin content. As a result, the octane value, i.e., anti-knock property of the fuel, is considerably raised whilst the sulphur removal that simultaneously occurs, due to the entire reaction taking place in a hydrogen atmosphere, increases the susceptibility of the finished product to further octane improvement by the addition of tetraethyl-lead.

The main purpose of installing the Platforming unit is to enable the refinery to produce a premium-grade motor spirit entirely from its own operations. However, as an alternative method of operation, the aromatisation reaction referred to above, coupled with the highly naphthenic character of one of the two available feed stocks, makes possible the production of a highly aromatic fraction which could serve as a source of benzene, toluene and xylenes.

The unit has a capacity of 800 barrels (approximately 95 tons) a day when running for motor spirit production. The production of aromatics requires somewhat more severe operating conditions, with a consequent reduction in capacity to about 600 barrels (80 tons) a day. The unit has been designed to operate on two different feed stocks, one being a light naphtha fraction (40-155°C) from the company's Peruvian crude, and the other a somewhat wider cut (30-195°C) from Middle East crude. In either case, the feed is first put through a stripper column to remove material boiling below 90°C, since such material is, owing to its chemical composition, not capable of economic octane improvement by putting it through the Platforming process.

As has been mentioned, this process results in desulphurisation of the charge. In the case of the Peruvian feed, such desulphurisation does not cause any undue accumulation of H_2S in the re-cycle gas owing to the negligible sulphur content of the material, but when Middle East crude is the source of the raw material, then its considerable sulphur content requires that the re-cycle gas be purified. The purification is carried out in a Girbotol unit, in which the gas is scrubbed with diethanolamine which is subsequently steam-stripped to remove H_2S, the latter being burnt in the heaters.

The gas-make on the unit is such as to render it self-supporting as regards fuel requirements and also to provide a surplus which is piped to the neighbouring gasworks.[2] As is usual in cracking plants, excess gas arising from inevitable slight fluctuations in plant operating conditions, and which cannot be fed to the gas-fuel system without upsetting its stability, is burned at a flare. To ensure that any combustion products (which in the case of the stack gases includes some SO_2 when operating on Middle East crude) are well dispersed, both the flare and the stack from the heaters have been built to a height of 100 ft.

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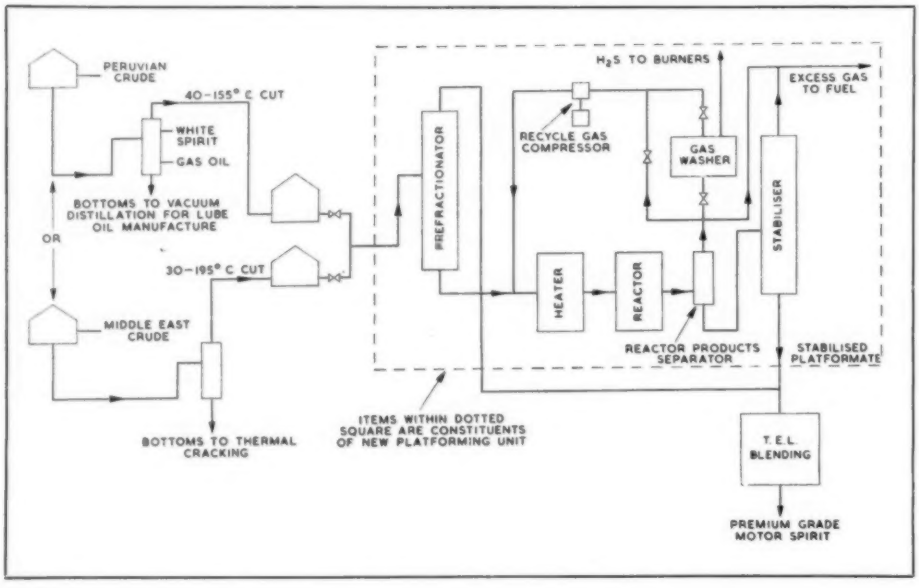

Simplified flow diagram of the Platforming process used by Lobitos.

POWDER METALLURGY AND THE SINTERING OF IRON

by A. J. LAST*

Modern powder metallurgy began with Wollaston's work on platinum. This article deals with the fundamentals of powder metallurgy, and discusses some of the problems of producing iron powders for subsequent processing

IN the period around 3000 B.C. the Egyptians became the first exponents of the art of powder metallurgy. They produced iron ornaments and weapons by the direct reduction of iron ore to sponge iron in a charcoal fire, and they made solid structures by forging the hot porous metal and cold-forming the useable shapes. In succeeding centuries, the sintering of powdered metal went unexploited until the technique was re-established by Wollaston nearly 5000 years later. Powder metallurgy was first used commercially when platinum ingots were made by compressing and sintering platinum powder. It was later applied in the production of tungsten billets required for the preparation of the metal filaments of electric light bulbs.

It was not until 1936, however, that iron powder was studied with the object of making moulded and sintered parts; the material used in this context was cheap Swedish sponge iron. During World War II the production of iron powders and powder parts was stepped up, and new applications of iron powder parts were discovered; the technique of powder metallurgy then proceeded to leap forward.

What is this art of powder metallurgy? Briefly, powder metallurgy is a method of producing certain articles from metallic powders by pressure and heat (though it should be noted that the term is often used with a wider connotation). Usually the two stages are separate and are termed *compacting* and *sintering* respectively. The compacting stage is carried out at room temperature in a die and a press. The compact then undergoes the sintering process, which is carried out in controlled atmosphere furnaces, the temperature of which may or may not be above the melting point of any one constituent. Sintering is usually followed by a sizing operation and perhaps by some machining. The sizing may be carried out in a die and press (in the same kind of way as is used in compacting the powder), or by coining or broaching. If dense iron and steel components are needed, a second sequence of pressing and sintering is sometimes employed. One sequence, however, suffices for most parts made in this manner.

The Raw Materials

Let us consider the case of powder metallurgy involving iron powder. How is the iron powder prepared in the first place? The processes for preparing metal powder fall into two categories: (1) physico-chemical processes; and (2) mechanical processes.

Iron powders are prepared in three main ways by physico-chemical means. The most important of these is the direct reduction of iron oxides with reducing gases. Using iron ores of very high purity, metal powders can be produced directly by this method. The general reaction for the reduction of a metal oxide of hydrogen or carbon monoxide is summarised thus:

$$M_xO_y + yH_2 \longrightarrow xM + yH_2O$$

or

$$M_xO_y + yCO \longrightarrow xM + yCO_2$$

Large quantities of sponge iron are produced by this method in Sweden, where there are reserves of very pure ore. The product, which has a very soft and spongy texture, is excellent for pressing. The process depends on the availability of ores of extremely high purity; since no slagging of waste material takes place in the process, magnetic concentration of the fine ground magnetites has had to be improved. For some time Sweden has been perfecting magnetic concentrating drums; it is now possible to leave as little as 0.07% silica as gangue in the final concentrate, a remarkably low figure that excels anything achieved by similar magnetic concentrating devices. Another somewhat similar process is the reduction of powdered mill scale (which is the waste product from the rolling and forging of billets) by carbonaceous reducing agents. This gives a good iron powder, but it does not have the same pressing properties as sponge iron as it contains hardening impurities (manganese and silicon).

Electrolytic iron is the product of the second of the physico-chemical processes. Iron powder produced by the electro-deposition of iron from a sulphate solution is generally rather harder than that produced by direct reduction. Its density can be controlled to some extent by current density, high acidity and low metal ion concentration, and the process always results in pure iron.

The third method is the carbonyl iron process, an expensive process which produces a very pure powder which has, as a rule, poor compressibility but good sintering properties. Carbonyls are obtained by passing carbon monoxide over spongy metal at specific temperatures and pressures. Iron pentacarbonyl—$Fe(CO)_5$—is a liquid at room temperature and boils at 103°C. When the pressure is reduced to one atmosphere and the temperature raised correspondingly, the carbonyl decomposes to re-form the metal and carbon monoxide; the latter is recycled to form more carbonyl to continue the process. The iron produced is collected, usually in sizes of ½-10 microns in diameter. It has been stated that only a few per cent of carbonyl powder added to commercial hydrogen-reduced powder can materially improve the product without affecting the cost.

Of the mechanical methods, shotting and crushing and milling of cast-iron or quenched steel particles, followed by decarburisation appear to be the most popular. Atomisation is used to some extent.

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The shotting process is interesting. Molten iron in a Bessemer converter is first blown to reduce the carbon to the 0.10-0.50% range; after slagging, the converter is tipped so that the stream of molten metal is poured on to a rotating steel wheel level with a bath of cooling water in a large, round tank. The resulting disc-shaped and porous granules are crushed and pulverised in impact mills and are finally annealed in a reducing atmosphere.

The greatest handicap in the development of the powder metallurgy of iron is the problem of obtaining high-purity powder at reasonably low prices, and this has an important bearing on the selection of parts to be made commercially by powder metallurgy.

Sponge iron is the lowest-priced powder, and with new methods of magnetic concentration will be used even more than it is now. Reduced iron powder with a purity of 96-98% iron is suitable for numerous applications in powder metallurgy; the price range is 7-10 cents per pound in North America. Other reduced iron powders (98 and 99% purity) are suitable for most applications where high accuracy and quality are required. American powders are more expensive than imported Swedish powders of approximately the same analysis. Very high quality iron powders (e.g., carbonyl and electrolytic powders) are used in special applications, such as magnetic cores and electrical contacts. The North American prices range from 15 cents to $1.00 per pound.

Fig. 1 indicates the scale on which powder metallurgy is used in the U.S.A. In 1953 two-thirds of the iron powder used in the United States for fabrication was imported; nowadays that figure has dropped to one-third. Taking other uses of iron powder into consideration—such as welding, powder cutting, concrete waterproofing and chemical applications—the total overall consumption of iron powder in North America approached 30,000 tons in 1956. Table 2 indicates some of the main applications of powder metallurgy and the materials involved.

Power Compaction

The press used for compacting may be operated either mechanically or hydraulically, and the pressure may be anywhere between 5 and 35 tons per square inch. When

Table 2. Materials and Applications of Powdered Metallurgy

Class	Example	Application
Production of non-alloyable metals	Silver-tungsten Silver-nickel Copper-lead	Electrical contacts Bearings
Metal and non-metallic mixtures	Cermets (Cr-Al_2O_3) Copper graphite Iron-plastic (ceramic)	High - temperature components Electrical brushes Magnetic powder cores
Materials with melting point too high for conventional casting	Tungsten Molybdenum	Filaments for electric lamps
Unique structural properties (a) Controlled porosity (b) Bonded carbides (c) Bonded micropowders	(a) Bronze Stainless steel (b) Cobalt-bonded tugsten carbide (c) Iron or permalloy powder with plastic	Bushings Filters Cutting tools Micropowder magnets
Mass - produced components with elimination or substantial reduction in machining costs	Iron Steel Bronze - impreg - nated iron Special alloy	Washers Gears, cams Gears, pump impellers Magnets

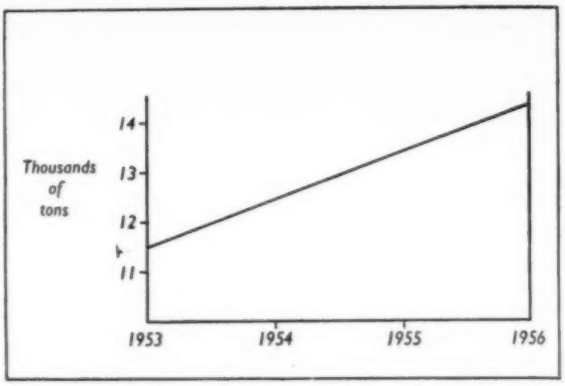

Fig. 1. Scale showing how powder metallurgy is being increasingly used in America.

two punches are used to compact the metal powder in the die, they are usually arranged at each end of the die and are operated to approach each other simultaneously. During this stage the voids between the particles are reduced in size, and therefore the density of the bulk of the powder increases. The voids are reduced by the deformation of particles so that they key into one another, the flattening of surface irregularities and the actual movement of the particles.

There have been several theories brought forward to account for the mechanism of powder compaction. They all agree on one thing, however: that the primary object is to bring enough particles together to produce inter-particle bonding which results in the "green" strength of the compact (i.e., the strength of the compact before sintering).

Atomic forces play a large part in the bonding of metal powders. The rearrangement of atoms in the surface layers of two adjacent surfaces will produce atomic links, provided the surfaces are close enough to each other. From this it follows that it is desirable to have the greatest surface area of particles as possible in order to produce the greatest number of contact points. In order to enhance this effect, particle size distribution and particle shape have to be carefully controlled. Plasticity also plays an important part; the greater the deformation on compression, the better the surface contact of the particles in the compact.

M. Yu Bal'shin[1] produced an interesting theory of powder compression which states that "if the height and relative volume of a compact decrease in arithmetical progression, then the pressure must increase geometrically". This can be expressed:

$$\log P = L V_r + C$$

where P is the pressure; L and C are constants depending on the powder and nature of compacting; V_r is the relative volume. Actual pressing curves $\log p = f(V_r)$ deviate slightly from the straight line pressing curves from the above equation. Bal'shin puts this down to changes in the properties of the powder during compression. Many other theories, of not quite such a generalised nature have been advanced and much research has been done in this field.

The pressing dies used in powder metallurgy have to be dimensioned to allow for contraction or expansion of the compact during the sintering stage. They must also have sufficient depth to contain the necessary volume of unconsolidated metal powder. *Usually the volume of the powder before compacting is about three times that of the finished product.*

The compacting tools usually consist of a die barrel in which the powder is poured; a lower punch which forms the bottom of the die barrel cavity and which serves as an ejector punch; a core rod extending through the lower

punch and die barrel for cylinders; and an upper punch which provides the pressure for compacting. Since metal powders cannot flow around corners, the tools must be made so that only opposing pressure forms the compact. Sideways movement in the die members has, until recently, been considered impossible. However, the National Radiator Co. in America has produced a side slide in a die which enables pressure to be applied from two directions at right angles to each other.

For parts having a variable thickness it is necessary to design die sets so that the various sections can be equally compressed. This is done by either springing the punches or using multiple punches. The primary concern in compacting a powder must be that the compression ratio—that is, the ratio between the apparent density of the powder and the relative density of the compact at any stage of compression—remains constant through the cross-section of the form. This ratio must stay constant whether the form is complex or not.

Sintering the Compacts

Sintering is the heart of powder metallurgy. It is the process which binds bodies together using pressure and/or heat. There are four main types of sintering: (a) sintering uncompacted particles with heat; (b) sintering with the simultaneous application of pressure and heat—in other words, hot pressing; (c) sintering compacts; and (d) sintering compacts with the production of a liquid phase.

Sintering is, in reality, a specialised heat treatment, for it implies the heating and cooling of a metal or alloy to impart certain characteristics of strength and ductility and other physical properties. Because of the large surface areas in metal powder compacts, special precautions have to be taken against oxidation or other chemical reactions. Protective atmospheres are used and these have the advantage, together with inherent porosity and non-metallic inclusions in the final sinterings, of the use of more drastic heat-treating procedures. The protective atmosphere prevents scale formation of the compact's surface, while the pores or inclusions act as inhibitors of grain growth.

F. N. Rhines[2,3] brought forward in 1946 an excellent composite theory on the mechanism of bonding and sintering. Essentially, this can be covered in five steps:

(1) An initial bond occurs, which exists at room temperature, between adjacent particles in a loosely heaped metal powder. This bond appears spontaneously at the points of metal-to-metal contact and is of a very low order.

(2) An increase in bonding during compaction by the application of pressure then occurs. This increases the number of point-to-point contacts as well as enlarging individual areas of contact. Interestingly enough, lubricants assist in the rearrangement of particles to provide greater surface contact; thus denser and stronger compacts are produced.

(3) On heating the compact, initial bonds or point welds form at the contact points between the particles. The mechanism of this is probably one of surface diffusion at the contact points.

(4) Bonding then spreads beyond the initial welds and the pores tend to spherodise. The chief cause of this step is surface tension.

(5) A continual decrease in the number of pores takes place, although some of the large pores grow at the expense of the small ones. This is explained by the vacancy migration theory, which states that lattice imperfections or small pores with high surface tension move or diffuse through the sintering compact towards large neighbouring pores which have a lower surface tension. Steps (3), (4) and (5) are three overlapping stages and they all account for most of the phenomena noticed in the sintering of metal powders.

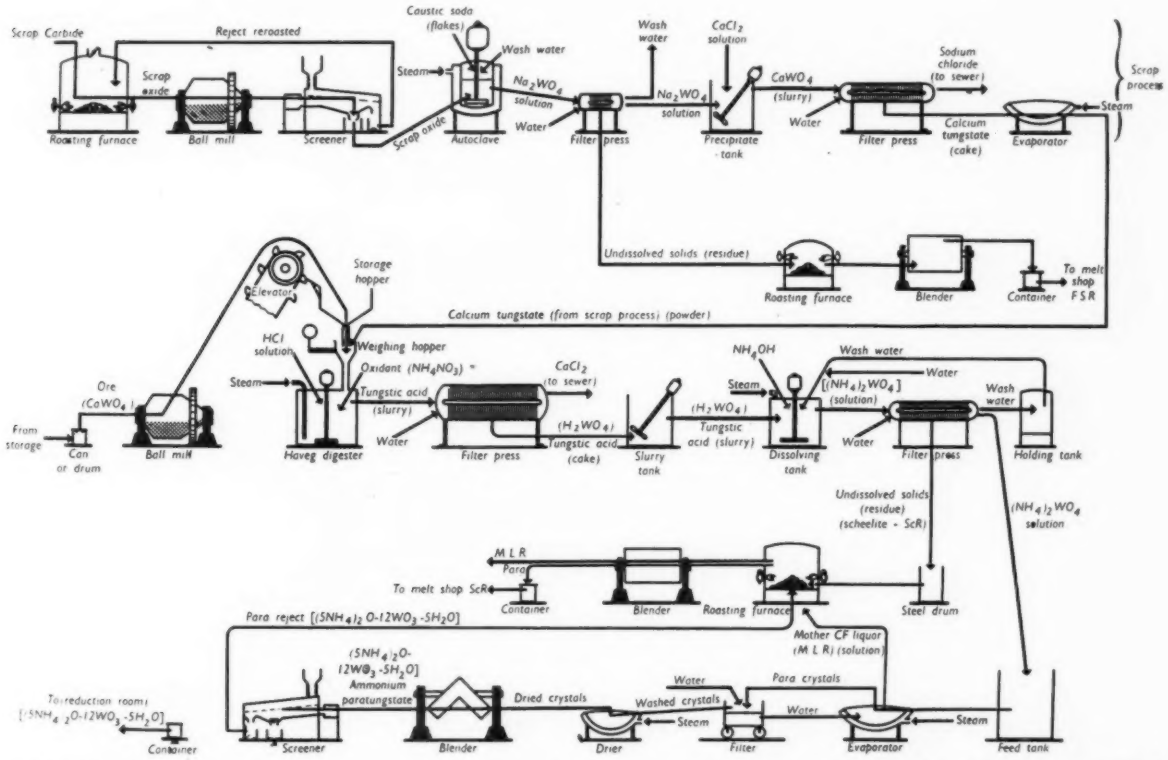

Fig. 2. Diagram of a plant for the preparation of ammonium paratungstate, a stage in the manufacture of tungsten metal.

Atmospheres are important in the production of iron sinterings. Iron parts need partially burned natural gas (hydrocarbon atmosphere) or dissociated ammonia, i.e., ammonia that has been "cracked" into nitrogen and hydrogen. Steel parts, on the other hand, require atmospheres with closely controlled dewpoints and carbon dioxide content in order to inhibit carbon loss from the compact. Hydrogen makes the best reducing atmosphere, but this gas is used only when its beneficial characteristics overbalance its high cost.

Uses of Powder Metallurgy

Once the decision is made that there are to be enough parts produced to warrant the high initial cost of powder metallurgy, it should be put before the die-designer or toolmaker with the specification indicating the metal, alloy or mixture to be used. If necessary, he will then re-design the part to make it easier to compress and give an efficient powder flow in the die. If the part is complex, he may divide it into two or more components of similar shape. The die will be designed next and a temporary set of tools probably made to determine the best condition for obtaining the correct densities, and to follow the pressing characteristics of the powder. The clearances and tolerances necessary to meet the specification will be computed. If a large output is contemplated, the dies may be made of carbide; otherwise they will be of die steel, probably chromium-plated.

The main object of design is, of course, the *economic* production of the parts in question. Good tool design is very important in this context, but economy can be fostered in many other ways, for example by the correct care of dies and by the use of good pressing and sintering practices; a thorough knowledge of the powder is also needed if the process is to be used to the best advantage.

Mechanical Strength of Sinterings

It is extremely difficult to give an accurate comparison survey of iron sinterings and low carbon steel owing to the many variables that have already been mentioned. However, taking a large range of density, from 6.5-7.5 g/cc. the ultimate tensile strength will vary from 20,000-40,000 psi, while the percentage elongation in a 2-in. gauge length varies from 5-20%. A normal low-carbon steel of full density (7.85 g/cc) has a tensile strength of 35,000-42,500 psi and an elongation of 30-40%. Re-pressing and re-sintering can give properties approaching and sometimes even exceeding those of low-carbon steels, but in most cases this extra step is unnecessary.

Owing to the rather poor properties of sintered pure iron parts, their application is mainly restricted to mild steel machine elements which are usually machined from iron and steel foundry products. The demand for parts of greater strength and wear-resistance leads to the development of sintered iron-carbon alloys or sintered steels. These are produced in three ways:

(1) Mechanical comminution of steel scrap or atomisation of steel scrap followed by decarbonisation.

(2) Pre-alloying iron powder by gas-carbonisation.

(3) Sintering iron-graphite mixtures and relying on diffusion to produce a homogeneous structure.

For densities from 6.8-7.2 g/cc the ultimate tensile strength of a sintered steel can be from 40,000-70,000 psi at 0.40% carbon and from 85,000-100,000 psi at 0.80% carbon. Heat treating can increase these figures considerably.

The Plastic Metals Division of the National Radiator Co.,[4] using electrolytic iron powder and gas carburisation of the finished parts (which were pressed with a heavy load), secured tensile strengths as high as 170,000 psi after quenching and tempering at 600°F. These results were on bars having original densities of 7 g/cc.

Re-pressing and re-sintering of steel parts is carried out quite extensively in the U.S.A. and yield extremely high tensile pieces.

Advantages and Disadvantages

It is often possible to make a complicated shape in one pressing operation which, on sintering, can be produced to accurate dimensions. This obviates any machining time or scrap wastage. Often a shorter tooling-up time is required for complicated shapes made by powder metallurgy; production may be commenced within weeks where tooling-up by normal machining techniques would take much longer. High rates of production can be maintained; it is quite normal to press at speeds of 1000-1200 pieces per hour from one press. Skilled machinists are not necessary for the presses; most of the work is done by unskilled labour. Wear resistance is improved considerably in the case of oil-impregnated low-density bearing parts. Many special alloys involving two immiscible metals cannot be made by any other process.

The size of the parts produced is limited, however; length is governed by the travel of the punches, and the transverse areas of parts are somewhat limited by the high compacting pressures. Powder metallurgy is seldom applied to the production of parts in small quantities, since the cost of the die would then account for too great a proportion of the total cost of the article. It has been stated that from 20,000 to 25,000 is an economic minimum.

Until recently, the application of powder metallurgy has been overstressed for promotional purposes. This perhaps has been helpful in some measure to enlarge and consolidate markets, but has caused many time-consuming, trial-and-error experiments to ensure that a particular part can be made. Today, two decades of experience have given metallurgists a better understanding of engineering design problems and the chance to be surer of this modern technique.

Design flexibility is usually the controlling factor when it comes to choosing methods. It controls not only the early decision of whether to use powder metallurgy or not, but also the coining or heat-treating methods to be used. A broad understanding of design in drop-forging, sand-casting, die-casting or screw-machine operation is essential for engineers designing powder metal sinterings.

Even with every processing care, powder metallurgy cannot yet be used for very highly-stressed parts such as transmission gears, but there is still a vast potential market for the method. We need only a few manufacturers to look at its uses with their eyes wide open and we shall soon see that present powder metallurgy ideas, big as they are, have just got started. Powder metallurgy has much growth ahead of it; and as it grows it is going to bring new wealth to industry.

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Table 2 is reproduced from the O.E.E.C. report mentioned above, as is also Fig. 2 on page 435.

French Students' Seminary

by Our French Correspondent

OVER 200 student engineers from 17 countries met in France recently to discuss problems of chemical engineering and to see some of the achievements of the French chemical industry on the occasion of the second seminary to be held under the auspices of the FIANEI, the International Federation of National Student-Engineer Associations. The French *Union des Grandes Ecoles,* which took a leading part in the formation of the Federation, was responsible for the organisation of the conference under the direction of André Henry, president, Claude Toulet, vice-president, and Roland Larue, general secretary. Although engineer associations from 12 countries throughout the world have already joined the Federation, invitations were extended to all countries regardless of their membership in the FIANEI. Delegates, mainly second-year students, came from Belgium, France, Germany, Indonesia, Israel, Italy, the Lebanon, Luxembourg, Morocco, Mexico, the Netherlands, Norway, Poland, Portugal, Switzerland, Tunisia and Viet-Nam. Unfortunately, Britain did not send representatives. The conference was supported by many branches of industry, private and nationalised, and the French Government also gave its active support.

After a preliminary gathering in Paris, delegates separated into specialist groups which went to various centres of the chemical industry in France. The electro-chemical group, 40 strong, left for Grenoble and the surrounding district, where some of the largest French electro-chemical plants are located. The places visited included the Neyrpic Hydraulics Laboratories; a chlorinated products factory of Péchiney, at which the processes are based on the electrolysis of sea salt; and aluminium treatment centres belonging to Péchiney and to Electro-Chimie d'Ugine.

The carbon-chemistry section first heard a lecture by Madame Danon, a collaborator with Professor Michel Magat in the study of radiation-induced cross-linking and grafting of polymers. This session was one of the highlights of the seminary. The group then visited the large Saint-Gobain research centre for chemicals in La Croix de Berny, near Paris, in the plastics department of which fundamental and applied research is conducted in connection with the Magat patents for grafted copolymers. The radiation laboratory is equipped with a cobalt "bomb" for radio-chemical studies. The remaining time was spent in the north, where the delegates were shown some of the most important factories belonging to the nationalised coal industry (*Houillères du Bassin du Nord et du Pas-de-Calais*). At Drocourt they saw the great benzole factories; in Mazingarbe the students visited the extensive chemical plants which produce ammonia, fertilisers, methanol and derived products, and which have an important ethylene-chemistry department. The Mazingarbe industrial centre, started in 1897, has developed into a vast project which includes also sections devoted to the coal industry—coal treatment, coke-making furnaces and two electric plants—and the chemical factories. A gas-producing pilot unit utilising the Koppers process and built in co-operation with the French coal industry research centre, Cerchar, has been working there since 1955. The process transforms in one step coal of high ash content into synthetic gas suitable for the synthesis of ammonia or of methanol. The pilot unit can handle up to 100 (metric) tons of coal and produce 180,000 cubic metres of gas every 24 hours.

The radiation-chemistry group of the conference, which was notably well attended and consisted of 60 members, met in Saclay. During the visits emphasis was given to the uses of radio-elements in the study of chemical reactions and corrosion. It was pointed out that, as the Lacq natural gas contains a very high proportion of hydrogen sulphide, a specially resistant steel had to be elaborated for the gas pipes, and radioactive tracing was used to study corrosion of steel by the gas.

The petroleum chemistry group started with a tour of the big Esso-Standard refinery at Port-Jérôme. At the French Petroleum Institute, which was exhibited in detail, Mr. Navarre, director of Esso-Standard, spoke on the future of the petroleum industry. France was a late comer in this branch of industry, he said, yet the initiator of catalytic cracking was a Frenchman, Houdry.

Education Discussed

Developments in the oil industry were also the main theme for the visits arranged for the educational section of the seminary. This smaller group was taken to the Shell refinery at Petit-Couronne, and also saw there the Shell-Saint-Gobain automatic Teepol plant, which produces a considerable amount of all of the detergents used in France. The students were also taken to the Rhône-Poulenc pharmaceutical laboratories at Vitry. But the main task of the educational group was to compare and discuss teaching methods and progress in the different countries and to see how they could be improved. The difficulties met with were of an unexpected nature. Reforms in the educational field have been a constant preoccupation in France for a long time, yet, with the exception of the French, Italian and Polish delegates, the students were prepared to accept uncritically the plans of their own teachers. It emerged from the discussions that in the countries represented at the conference there are two main approaches to chemical engineering studies—via specialised schools and universities.

One of the main questions raised was that of specialisation. Should the student be specialised or be given a general training so that he may later choose between the different branches of chemistry? The choice is dictated largely by economic conditions and individual tendencies. In countries where the need for chemical engineers is sharpest—and France is one of them—the student will not hesitate to specialise because he is assured of finding a job, whichever specialty he has chosen. Another point examined was the importance to be given to mathematics in chemical engineering studies. Here, opinions differed widely, and the evident conclusion is that there is need for theoreticians as well as for practical workers.

The ages of those attending ranged from 21 to 25, and the delegates included 15 women students, about half of whom came from French engineering colleges. This proportion of women was surprisingly small when compared with the number of women engaged in scientific work. The seminary ended on an optimistic note. International bonds of friendship had been established and strengthened and a better knowledge of industry gained by the students. Next year's FIANEI conference will take place in Belgium, where an important meeting in the summer is being planned by the Belgian Federation of Student-Engineers. It will be held in Brussels during the World Fair, and aims to attract 1,000 students. Theme chosen is "engineering formation".

SOME NOTES ON CYLINDRICAL VESSELS UNDER INTERNAL PRESSURE

by S. D. SCORER, A.M.I.Mech.E., M.I.Mar.E.

Practical considerations in maintaining the safety of cylindrical pressure vessels are discussed in this article; methods of measuring thickness are outlined, and procedures of non-destructive testing are described

BY ordering a chemical pressure vessel to the appropriate British Standard Specification, the purchaser is assured that the material, design and construction will conform to a certain quality approved by the leading representatives of his industry. Once the vessel has been installed, however, its subsequent working life and safety depend upon the treatment it receives, and here it may be stated that it is the responsibility of the owner—through his employees or a survey authority—to see that the vessel is safely maintained.

Fortunately, the design factors affecting the strength of the various physical forms of pressure vessels can be expressed simply. For example, the safe working pressure of a plain cylindrical vessel exposed to internal pressure depends directly upon the stress induced in its shell by the internal pressure and the thickness of the shell. It also varies inversely as the shell diameter, or, $p \propto ft/d$

where p = internal pressure;
f = working stress;
t = thickness; and
d = diameter.

Given a constant pressure and internal diameter the only variables are the shell thickness and the stress. Similarly, in the dished ends usually fitted to this class of vessel, $p \propto ft/r$; where r is the end-plate radius.

Problem of Erosion

If the vessel holds corrosive substances, or is provided with mechanical stirrers likely to cause erosion, a reduction in thickness of the shell must be expected. The working stress (f) is a function of the ultimate strength of the material, and with mild steel is usually taken as $\frac{1}{5}$ of the ultimate strength for design purposes. Thus, if a working f of 12,000 psi is assumed to gave a safety factor of 5 with an initial thickness of $\frac{1}{4}$ in., a reduction of t to $\frac{1}{2}$ in. will mean that f has increased 1.5 times. The factor of safety is then only 3.33, instead of 5. This is not so serious, but if the thickness (t) is reduced to just under $\frac{1}{4}$ in., f rises to 40,000 psi. This is near the yield point of mild steel, and at that stress the metal will begin to deform and may even rupture. By measuring the thickness at suitable time intervals, a check on the stress and, consequently, on the safety of the vessel is obtained.

The method of measuring t depends upon the way in which it is being reduced. If the wasting is due to internal corrosion, the reduction may take the form of pits and blotches over the surface of the metal. A skilled engineer-surveyor (see Fig. 1) can decide which are the most badly-attacked areas and, by means of a special depth-gauge, or with the aid of a straight-edge, assess the general depth of wasting and so compute the average remaining thickness of the metal. In a badly-corroded vessel considerable experience is necessary before an accurate estimate can be made.

When the corrosion is of the smooth type, a form of corrosion which presents few and minute irregularities of surface for measurement, or if the metal is generally reduced by erosion, another method of measuring t can be used. It is particularly applicable to thick-walled vessels where a drill test would be undesirable because of the difficulty of fitting a pressure-tight screwed plug after the test.

The method is simple, if tedious to use, and employs a rod or straight-edge having a length a few inches less than the original diameter of the vessel. A micrometer gauge is firmly secured to one end of the rod, and the distance between the other end of the rod and the micrometer point is accurately set to the original internal diameter of the vessel. By means of this measuring rod, readings of the corroded internal diameter are taken over at least two diameters and at four or more planes along the height or length of the vessel, and the results noted. It is then an easy matter to calculate the average depth of wasting at each plane, and so arrive at the average maximum depth. This, in turn, gives the average remaining thickness.

This method tends to ignore the effect of large blotches, but there is a safeguard. When the thickness of the 60,000-psi material is such that the stress approaches 40,000 psi, the factor of safety on the ultimate strength is only 1.5, and the metal is nearly at the point of elastic failure. If it is laid down that the factor of safety on the yield point must never be less than 2, then, on the basis of 60,000-psi material, the factor of safety on the ultimate strength must never be less than 3. Consequently, in the conditions assumed, the maximum permissible stress must never exceed, $\frac{60{,}000}{3}$ or 20,000 psi. At this stress the vessel is considered to be no longer safe for its original assessed working pressure. In the example cited, where the initial thickness was $\frac{1}{4}$ in., and the initial working stress was

Fig. 1. Engineer-surveyor about to examine a chemical autoclave for points of weakness.

Fig. 2. Testing metal thickness of a vessel wall by means of an electronic ultrasonic meter.

12,000 psi, the minimum thickness for a stress of 20,000 psi would be 0.45 in. At that thickness the vessel would have to be scrapped or its working pressure reduced.

To avoid having to alter the working conditions of a vessel at a moment's notice, measurements of thickness should be made periodically. By plotting thickness against the number of hours worked, a curve showing the rate of wear can be established and, by extrapolation, the number of working hours left before the minimum permissible thickness is reached can be estimated. It must be emphasised that when measurements of t have been made it is not the thickness value then obtained that is important, but the probable thickness value at the end of the next working period.

A disadvantage of the measuring methods so far described is that they assume the original thickness to be equal to the original design figure. If through some mischance, the original plate was less in thickness than its design specification, the calculated remaining thickness would be that much less. It is always advisable to confirm the estimates by drill-testing the parts of supposed least thickness, although there may be a subsequent difficulty in tightly screw-plugging the test holes.

Non-destructive Testing

Within recent years a method of non-destructive testing of metal thickness has been developed (see Fig. 2). This method uses an ultrasonic thickness meter which operates by virtue of the properties of ultrasonic vibrations and quartz crystals. When a quartz crystal is placed in liquid contact with the surface of a metal and the crystal is vibrated by a high-frequency electric current, sound waves are transmitted into the metal. These strike the interior surface of the metal, and are reflected back. The time taken for the total travel is a function of the thickness. By reinforcing each pulse as it returns to the crystal, a state of resonance can be induced. Because of the difficulty of measuring the very small time intervals, the instrument is designed so that the fundamental frequency, and hence the thickness, of the metal under test can be determined. The instrument can operate with a range of thicknesses from $\frac{1}{16}$-12 in., with an error of $\pm$2-3%.

Increase of p

From the foregoing, we have seen that a reduction in thickness results in an increase in the working stress, f. It follows, therefore, that f will also increase if p, the internal pressure, is increased, and this can increase accidentally in a number of ways. For example, into a small autoclave an assistant chemist inadvertently inserted a double charge of the compound with which he was experimenting. Luckily, in this case, when gentle heat was applied, the dire results were not fatal. The vessel had a solid-drawn shell and end and a flat cover secured to the body flange by bolts. The bolts, under the abnormal pressure, first stretched elastically and then broke. They showed a waisted effect typical of the tensile failure of a specimen in a testing machine. The provision of a bursting disc or safety valve on the vessel would probably have relieved the excessive pressure and prevented the damage.

Often when a vessel of relatively light construction has to be supplied with steam for a short time, to speed the process the steam is led in at a pressure much greater than that for which the vessel was designed. Usually, the shortness of the period of steam admission, together with condensation and radiation effects, reduce the steam pressure to a safe value. Occasionally, they do not, and an accident results. Safety can be assured by providing a vent pipe to atmosphere suitably proportioned to the steam

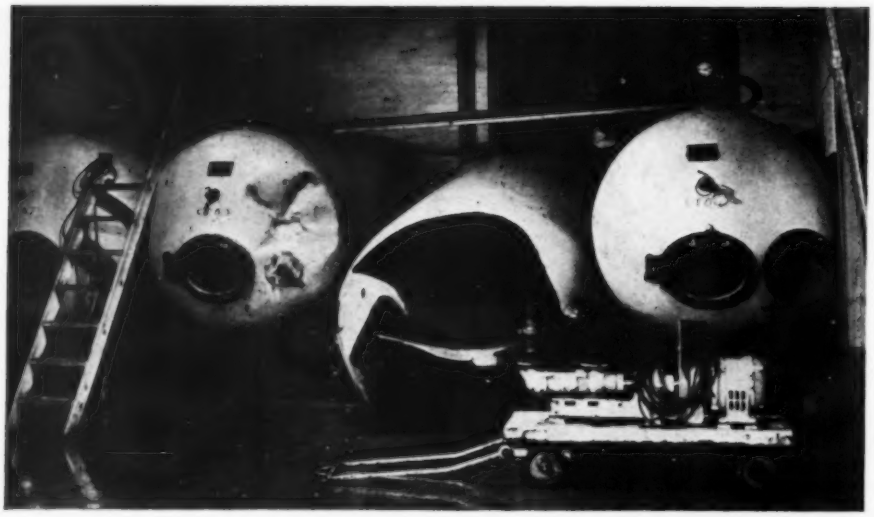


Fig. 3. An actual example of the type of failure in liquid containers caused by excessive pressure.

Fig. 4 (below). Damage caused by an explosion in a compressed-air receiver.

inlet pipe. Thus: $P \times a = p \times A$, where P is the absolute pressure of the steam at the inlet, and a is the inlet pipe area; p is the absolute pressure for which the vessel was designed and A is the area of the open vent to atmosphere.

Higher Pressures

For higher pressures and larger quantities of steam used in a closed vessel, the law and safety stipulate that a reducing valve must be inserted between the high-pressure source and the low-pressure, steam-using appliance. In addition, a safety valve and a pressure gauge must be fitted on the low-pressure side of the reducing valve. No legal rule exists for the size of safety valve (in point of fact, to provide safety valve area capable of relieving all excess pressure in the event of reducing-valve failure would be almost prohibitive commercially). But a rough and acceptable precaution is to fit a valve with an area equal to 1.5 times that of the reducing valve or of the low-pressure pipe, whichever is the less. Thus a 3-in. bore low-pressure pipe would need a safety valve of about $3\frac{1}{8}$ in. bore.

It must not be assumed, however, that only steam or chemical pressure can cause an increase in the internal pressure. Fig. 3 shows what happened to a liquid container when the pressure was increased by an unusual mischance. The containers were made of aluminium and were used to store liquor pumped from a road tanker. One large and one small vent cock were fitted at the highest point of each container and, before pumping started, it was the operator's responsibility to open the cocks which let the air out as the liquid entered. When the containers were filled the vent cocks were closed and the liquor was forced out of each container as required, by compressed air at 30 psi. A small safety valve set at that figure was provided, but rather to give warning of over-pressure than to relieve it. On the day of the accident a new attendant was instructed to fill the containers. Everything apparently went as normal until suddenly the shell near the front end-plate of the middle container ripped and the front end-plate blew out. Inquiry revealed that only the small air vent had been opened. The pump was of a screw type, capable of working against considerable resistance, and, by continuing to pump liquor into the container, it compressed the air trapped above the liquor surface. The small safety valve opened, without effect and, apparently, also without significance to the attendant.

The widespread use of compressed air in the chemical industry, for pumping and other purposes, is not without its hazards. When air is compressed under approximately adiabatic conditions, as in a single-cylinder, uncooled compressor, its temperature is increased. At 10 psi its compressed temperature will be about 140°F; at 80 psi, about 430°F; and at 120 psi, about 525°F. Moreover, it is almost impossible to stop small quantities of compressor lubricating oil being carried over with the hot air. If the oil has a flash point of, say, 425°F, it is surprising that it does not regularly ignite and cause trouble. Cylinder and pipeline radiation effects reduce the danger, but when compressor maintenance is neglected, leaking valves may allow heated air to flow back into the cylinder for re-compression. Carbon deposits on the cylinder head or piston may also reach red heat, and if an incandescent particle is carried over with heated oil-laden air, an explosion is almost certain. Dust drawn in through the compressor inlet accentuates this effect.

In such conditions the sudden ignition of the air-oil vapour mixture in the air receiver creates an internal pressure which is more than the receiver can withstand (see Fig. 4). The remedy, keep the compressor in good order, drain the receiver periodically every day and fit a fusible plug in the air line between the compressor and the receiver. Such plugs are usually designed to melt at about 380°F, and will thus give warning of the approach of excessive temperature conditions.

Fig. 1 is reproduced by courtesy of Monsanto Chemicals Ltd. Figs. 2, 3 and 4 by courtesy of Vulcan Boiler and General Insurance Co. Ltd.

NUCLEAR ENGINEERING IN JAPAN

Present and future prospects of the Japanese market for nuclear equipment

THE Japanese shortage of power resources for her large and expanding heavy industries, coupled with her late start in atomic energy development compared with Western countries, makes the Japanese market potentially one of the largest for atomic equipment, and perhaps the largest in imported equipment. The association in the public mind of the atom with the dropping of bombs on Hiroshima and Nagasaki delayed Japanese interest in atomic energy, but over the past three years, and particularly during the last twelve months, enthusiasm has been rising steadily. Many big industrial concerns in the country have formed atomic research and application departments; moreover, they are tending to resume their own pre-war affiliations and to organise themselves into groups reminiscent of those formed in the United Kingdom. The electric power companies, who are faced with the continued shortage of power from conventional sources, have declared that 1000 megawatts of electricity must be available from atomic sources by 1965 and 10,000 megawatts by 1975. Universities are negotiating to acquire experimental reactors, prospects for marine propulsion by atomic energy are being investigated and an Atomic Vessels Research Committee has been established jointly by the Government and industry. Another joint organisation, the Atomic Energy Research Institute, has purchased a "water boiler" research reactor from America and full use of this is expected to commence this summer. The Government has created a structure of administrative control, and new legislation is being drafted to cover the import and use of large-scale reactors and other matters.

As Japan is the most highly industrialised nation in Asia, the country can serve as a shop-window for industrial equipment. British atomic achievement, particularly the rapid development of a practical power programme with natural uranium reactors, is respected in Japan and this respect has been strengthened by the visits of Sir Christopher Hinton to Japan and of representatives of the Japanese Government and industrialists to the United Kingdom for discussions on atomic energy matters. As the quality of the best industrial work in Japan is of a standard not easily surpassed elsewhere, there will always be a tendency to manufacture as early as possible at home Japanese requirements of equipment, and it is foreseeable that the market may turn out to be one for royalties and licence agreements as much as for the supply of large quantities of goods. There will be abundant opportunity for making sales, however, particularly where the products are not needed in sufficient quantity to make their local manufacture worth while or where special techniques are involved. Powerful competition, however, is to be expected from the United States.

Although the Japanese atomic energy world is, at present, in a ferment of change, 600 firms and organisations interested in atomic development founded last year the Japan Atomic Industrial Forum—an organisation having a declared object to co-ordinate industry's part in Japan's atomic programme. It sets out to effect liaison amongst private business; the exchange of information; the dissemination of knowledge on atomic energy; and the maintenance of contact with foreign atomic energy organisations. Already, it has helped to arrange visits to Japan by a number of distinguished foreign experts and it dispatched an inspection mission on a three months' tour of the United States and Europe and sponsored a joint United States-Japan atomic industrial forum in May this year in which 16 Asian and Pacific countries were invited as observers. Among industrial developments being made or being considered, the Mitsubishi Group are studying a plant to establish a new company to co-ordinate the development of atomic energy commercially. It is intended that the new organisation would eventually deal with the construction of reactors and allied equipment. Although the question of how atomic power developments in Japan should be financed is the subject of much controversy, it seems likely that the Electric Power Development Co. (an organisation of which the Government is the major shareholder) will play a significant part when power reactors are imported and erected.

The Academic Side

On the academic side, a number of Japanese universities are now getting under way with work with cyclotrons or on the construction of cyclotrons. The Kyoto cyclotron of 16 MeV, which has been completed for some time, is at present the largest in the country. At the Tokyo University Institute for Nuclear Study a 20-MeV cyclotron is on its way to completion, and the Institute may in the future acquire a small experimental reactor. Osaka University has a small experimental cyclotron, and there are plans for the development of wider nuclear research studies at this university. Osaka and Kyoto Universities are joining together to import a research reactor which is to be built in the area around these two cities. A committee has been formed to deal with the special problem of siting and establishing such a reactor, and it is sending its members overseas to investigate such matters as the disposal of cooling liquids, etc. Other universities are proceeding with experimental work in various atomic fields, and there is a large possible field for the United Kingdom in the supply of scientific instruments to all these institutions.

The Government organisation in atomic energy matters is, briefly, as follows: there is a Cabinet Minister who is the Director of the Economic Planning and chairman of the Japanese Atomic Energy Commission. The Atomic Energy Commission is the highest Government advisory body, and, in addition to its chairman, it has two full-time and two part-time members. It meets once a month and carries considerable influence in Japanese atomic affairs. Also there exists a Parliamentary Joint Committee on Atomic Energy comprising a chairman and ten members drawn from the main political parties. The secretariat and executive body of the Atomic Energy Commission is the Atomic Energy Bureau.

TANK CONTENTS NOMOGRAM

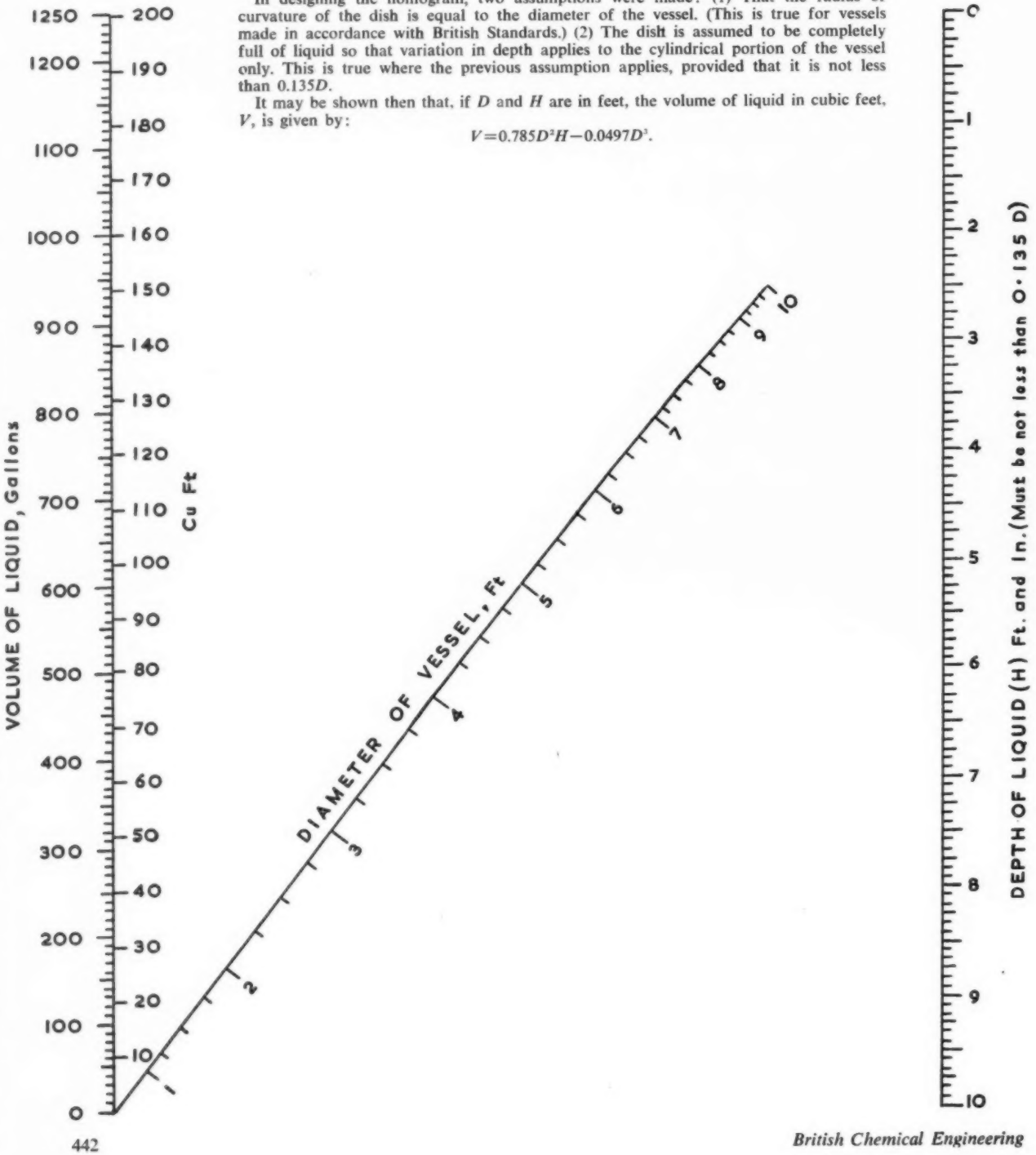
By D. B. Purchas, B.Sc., A.M.I.Chem.E.

This nomogram can be used for determining the depth of liquid in a vertical cylindrical tank fitted with a dished end. It is necessary only to know the diameter of the vessel D and to take the measurement of the depth along the axis H. Liquid depth is probably best measured with a dip tape to find the vertical distance, h, of the liquid surface below some fixed point on the lid or manhole of the vessel. The height, L, of the fixed point above the bottom of the vessel can be established either from the engineering drawing or by actual measurement. The liquid depth, H, is then equal to $L-h$.

In designing the nomogram, two assumptions were made: (1) That the radius of curvature of the dish is equal to the diameter of the vessel. (This is true for vessels made in accordance with British Standards.) (2) The dish is assumed to be completely full of liquid so that variation in depth applies to the cylindrical portion of the vessel only. This is true where the previous assumption applies, provided that it is not less than $0.135D$.

It may be shown then that, if D and H are in feet, the volume of liquid in cubic feet, V, is given by:

$$V=0.785D^2H-0.0497D^3.$$



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AMERICAN LETTER

American Manpower Problems

Our American correspondent describes the measures taken by American industry to meet its man-power problems

ALTHOUGH the curve for strength of technical man-power in the United States has turned upwards for the first time in six years, there is still great anxiety about the shortage of technologists. Like the mountain of truth, the campaign to overcome this has many sides. The measures taken to extend chemical engineering training were discussed in this column last year.[1] But American firms have a further remedy which is rare in Britain; they recruit abroad. This raises a fresh problem. How is the intake being assimilated?

American firms claim that in a few years engineers of foreign origin are so completely assimilated that for all practical purposes it is impossible to tell any difference between them and the graduates of American universities. The recruits tend to be younger men with less that ten years' experience after completing their training. Some companies have secured their services by sending special recruitment teams abroad, but others have used joint agencies or the ordinary professional agencies in the countries where they hope to find their men. In general, the attitude is that recruitment abroad is a short-range solution until better reserves are built up in the schools.

Naturally, Europe is the main source of this infusion, and it is therefore interesting to note that the Organisation for European Economic Co-operation is sponsoring a survey of scientific man-power for its sixteen member countries. Dael Wolfe, executive officer of the American Association for the Advancement of Science, has been named leader of the team of specialists carrying out these studies.

To return to the U.S.A.—what are the current estimates of the position and what steps are proposed to deal with it? Chairman J. L. Collyer, of the B. F. Goodrich Co., has stated that, in the next ten years, America will need 100,000 more engineers and scientists than current training trends indicate will be available. The impact is likely to be more serious on the lower-paying government and educational institutions. In the middle-West one agency has already reported that they had four to eight jobs for every man available—and this was despite the fact that, in 1956, there was 15% increase of Bachelor degrees in science and 17% in engineering over 1955.

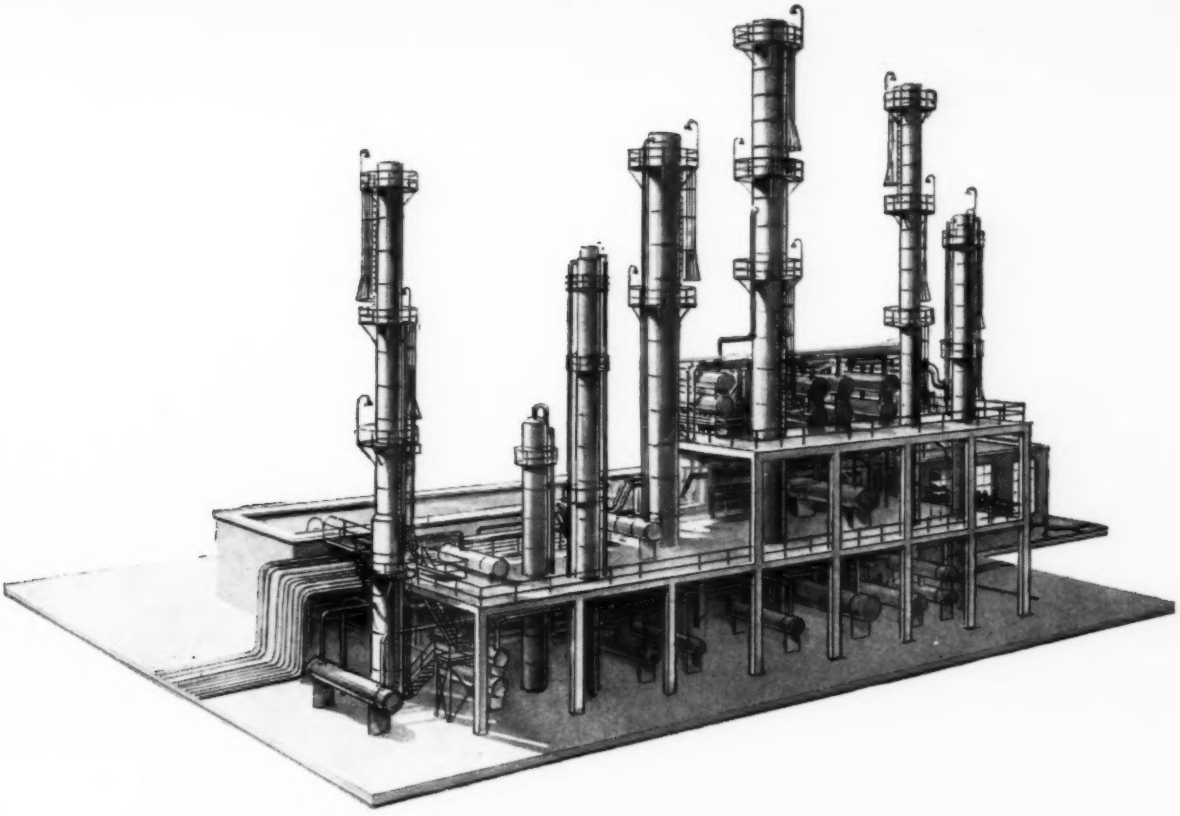
At the root of it all is the status of science in the schools. "Best wishes to you" concluded a telegram from President Eisenhower himself to the Eighth National Science Fair. In his message, the President wrote: "Science clubs of America are performing a splendid service in our high schools across the land. As they recognise and encourage the ability of our student scientists, they help to ensure the future strength of our national economy and the freedom of all." Nearly a score of communities and States—seeing the writing on the wall and heeding the warning—have developed major programmes to interest young people in following scientific careers and to provide facilities for scientific training. Most comprehensive is the effort in Oklahoma, where they have set up a Frontiers of Science Foundation. This body has three basic aims. It promotes general science information, more formal science education and the construction of science installations. Secondary-school principals report increased enrolment in science and mathematics courses attributed to the activities of the Foundation. But if the supply is short and the reinforcements will take many years to arrive, it becomes more important to use available man-power efficiently.

How many scientists are doing jobs within the compass of a trained technician? Maynard Boring, reporting to the National Committee for the Development of Scientists and Engineers, put heavy stress on the need for recruiting and training greater numbers of scientific and engineering technicians. These are men and women schooled in the fundamentals of science and capable of jobs at a level between that of the graduate professional and the industrial craftsman. They can often take some of the load of computing or experimental work from the graduate.

Then there are the blinkers. For example, does McMahon Act secrecy pay? The recent agreement on the exchange of atomic information with Great Britain suggests that it does not. There is one interesting development common to a number of large enterprises who have the capital to match their vision. An increasing number of companies are sponsoring fundamental research with no immediate product or process in view.

They realise that their research progress, which, naturally, is tied in with their economic progress, depends on an accumulated store of fundamental knowledge. This, they see, is being constantly depleted, and it is in the replenishment of this store that their current research programmes are aimed. Admittedly, industry has greater scope for exploratory, applied and process research, but it is actively conscious of its duty to encourage and assist American universities in their basic research programmes, who, rightly, concentrate their research efforts on fundamental studies. How well industry is carrying out its responsibilities may be gauged from the fact that it provided over $8 million as unrestricted research grants in the school year 1954-55, a sum which in no way included the amounts invested in research done under contracts. It is said that today private industry is spending over $2.5 billion per annum, balanced by an equal amount of spending by public bodies, all on basic research—this compared with a total of $1 billion in 1941. It is surely here that the creative seeds will be found and nurtured through their early, tender days.

[1] *British Chemical Engineering*, 1956, **1**, 276.



UDEX in England

The British Petroleum Company Limited has awarded us the contract for the engineering design and procurement of its first UDEX plant. The unit recovers a highly aromatic fraction for use in aviation fuel by the extraction process licensed by the Universal Oil Products Company.

This plant is one of several process units that we are presently engineering for BP Refinery (Kent) Limited.

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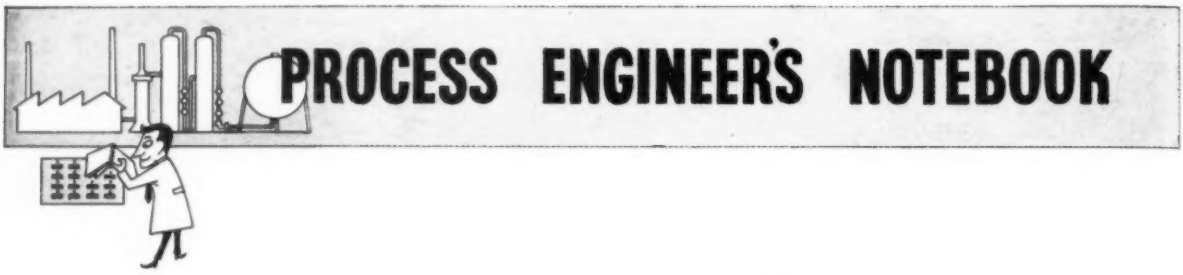
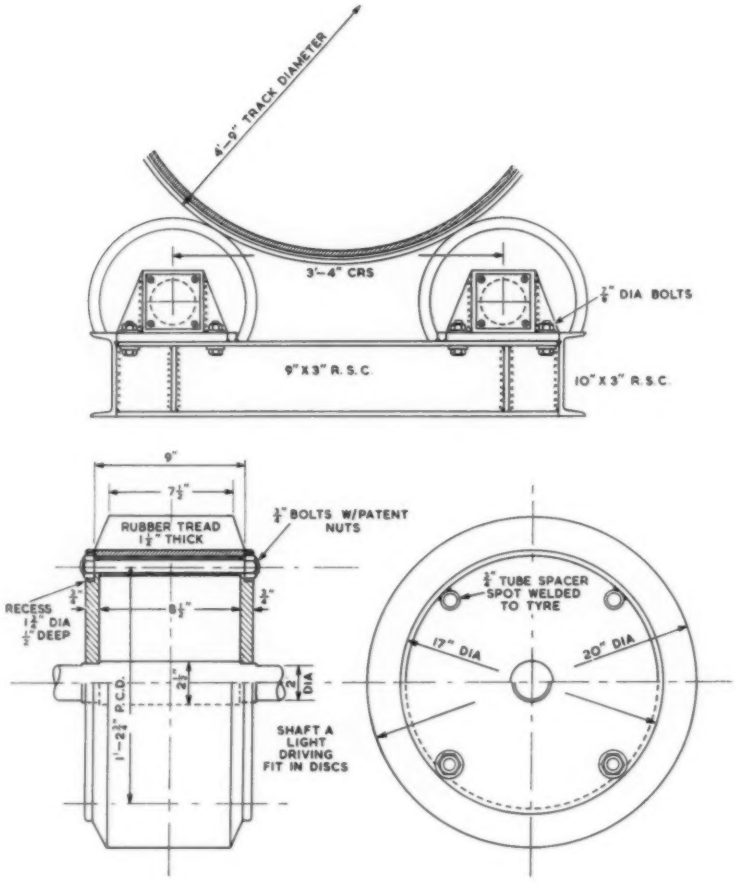


Repairing a Rotary Ball-mill

THE ACCOMPANYING diagram shows some of the steps taken to repair a rotary ball-mill which, in addition to badly worn rollers, had suffered a fractured track ring. The difficulties of undertaking a satisfactory repair were exacerbated by the fact that the original rings were welded direct to the ball-mill shell. Essentially, the repair consisted of substituting "tank" (military variety) rollers for the worn rollers and replacing the track rings by additional sections of shell. The shell sections had to be in contact with the rubber-tyred tank rollers.

The idler rollers were 20 in. overall diameter by 16 in. inside diameter and were fitted with a solid rubber tread, 1½ in. thick and 9 to 7½ in. wide. According to the roller manufacturers, these were suitable for a load of 62 cwt. when running at 12 m.p.h. The spokes of the old track rings were burned off and the rings replaced by 4-ft-wide mild-steel bands, fabricated from ¼-in. plate. These were fitted to the shell of the drum, the internal diameter of which was 4 ft 6 in. The rollers were fitted at 3 ft 4 in. centres to run on these bands and were arranged to cover the whole 20-ft length of the mill. The radial load on each roller then amounted to 2.94 tons compared with the maximum allowable loading of 3.1 tons. The width of the bands (4 ft) is such as to allow for the fitting of double sets of rollers, should it be desired to carry a greater load in the mill.

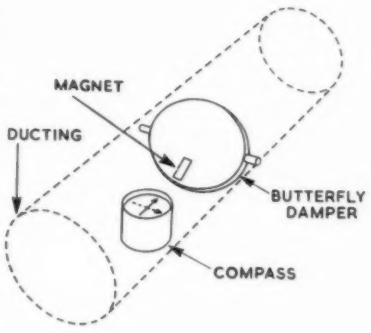
The diagram shows details of the way in which the rollers were arranged using spherical-seated roller bearings. The track bands were accurately rolled in two halves to 4 ft 9 in. outside diameter, and provided with temporary light lugs to assist in fitting them to the shell of the mill. To overcome the difficulty in rolling the last few inches of each segment to the correct radius, the bands were made 6 in. longer than necessary at each end. After rolling, the surplus was burned off to leave two accurate half cylinders with ¼-in. gap at each joint.



The drum, which was ½ in. greater in diameter one way than the other, was set on blocks and two long centre sticks were fixed across each end. These sticks projected several feet beyond the shell. Four lines were then run from the ends of the sticks, roughly parallel to the axis, and so adjusted that they were concentric with the spur wheel of the drum and very nearly concentric with each of its ends. The bands were then bolted firmly, but not excessively, in position and, by means of steel packing strips, located concentrically with the four lines. They were next spot welded to the packs and the shell and the axial gap filled by welding. The temporary lugs were then burned off. Packings were next tapped into the space between the bands and the shell, filling it completely, and the bands were then welded to the shell. During this operation a radiused template was applied to ensure that there was no distortion of the profile of the tracks. Finally, all rough places were buffed over with a portable grinder, leaving the tracks smooth and quite accurate. The drum rollers were bolted to the bedplate and the mill lowered into place. When put into operation it was completely successful and ran quieter than it had previously when fitted with the metal rollers. J.Y.

Compass Indicates Position of Damper

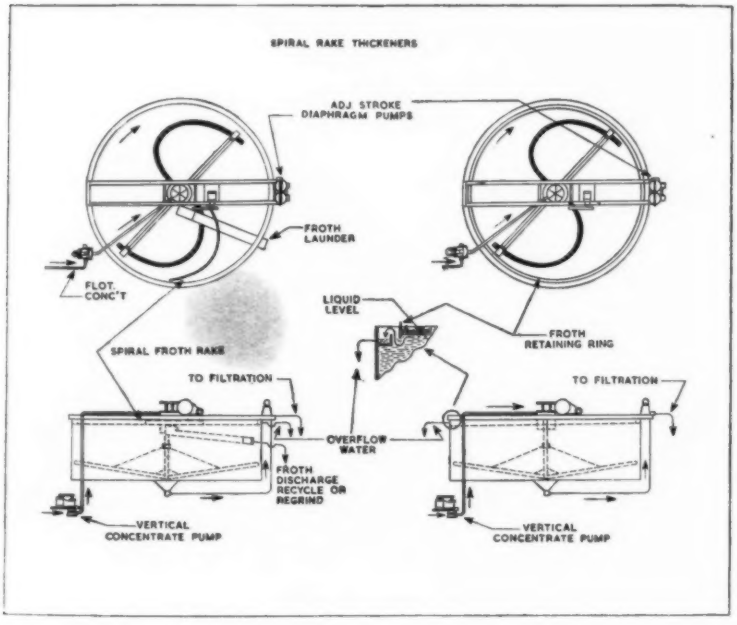
THE PROBLEM WAS to find a method of indicating the position of a butterfly damper fitted inside a length of plastic ducting in an installation where a pointer and scale could not be used. One solution was to attach a small magnet to the butterfly near its lower edge. A compass was mounted beneath the ducting to indicate the position of the magnet and, therefore, the damper. For example, with the damper closed the compass needle pointed in an axial direction. With the damper in the open position the needle pointed at right angles to the axis of the ducting. The use of the small magnet fulfilled the important condition that, whatever device was used, it must not cause any significant increase in pressure drop. The magnet was attached to the damper by means of a layer of transparent adhesive tape, followed by applications of epoxy cement and strips of glass fibre. This procedure gave a secure and protective fitting. The magnet itself was a good-quality, well-damped instrument.



Keeping Froth from Thickener Overflow

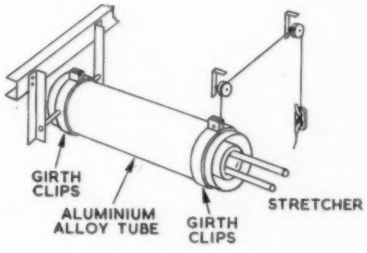
THE ARRANGEMENTS shown in the diagram can be used to prevent the presence of froth in the overflow from thickeners and hydro-classifiers, especially in cases where the use of wetting agents or water sprays for froth dispersal would interfere with the flotation process. In the first method, a single spiral froth-blade is fastened to the thickener shaft in such a manner as to direct the froth from the surface of the liquid towards the centre of the machine. The froth is then received into a closed launder which extends through the side of the tank and allows the froth to be discharged for further treatment.

The second arrangement employs a retaining ring fitted near the thickener periphery. This results in the accumulation of froth on the liquid surface, while overflow water free from froth is forced downwards under the lower edge of the retaining ring before being discharged. If the froth and floating solids retained in the thickener do not subside quickly enough, then water sprays may be used to hasten the settling process. This item is published by courtesy of the Denver Equipment Company of Denver, Colorado.



Convenient Stretcher Storer

ON SOME PLANTS where there is even a slight risk of toxic hazards, it is useful to have a stretcher handy in order to transport any casualty to the first-aid department. Cases have been known where stretchers left near plant have deteriorated and so been rendered useless. One way of storing a stretcher in a convenient and cheap manner is to fabricate a tubular container from sheet aluminium. This can be reinforced at either end by girth clips and suspended from the ceiling



or from part of the plant structure by pivots attached to the clips. The open end of the tube is suspended clear of the working space by means of cable and pulleys, as illustrated in the accompanying diagram.

When the stretcher is required, the open end of the container can be lowered gently to allow the stretcher to be withdrawn.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

Book Reviews

Principles of Engineering Heat Transfer

by Warren H. Giedt.

Van Nostrand Co., Inc., Princeton, N.J.; Macmillan & Co., London; 1957, 372 pp. 48s.

THIS book is intended to introduce the subject of heat transfer to the undergraduate for whom the specialised volumes, such as MacAdams, Kern, Shack and others, are scarcely suitable. The appearance of a book written on this subject for a student audience emphasises the great importance of heat transfer in industry, as well as the rapid strides which are being made in this branch of engineering.

Conduction, convection and radiation are covered in the text, each branch of the subject being dealt with in a qualitative manner before quantitative detailed treatment is given. Of the book's fourteen chapters, three are devoted to steady, one- and two-dimensional conduction, whereas transient conduction is treated later in the book.

Convection is preceded by chapters on potential and viscous flow, and has four chapters devoted to it. These subdivide the subject into laminar and turbulent flow and deal with the familiar problems of plain surfaces and ducts. These aspects of the subject are followed by an account of the behaviour of submerged bodies and high-velocity flow. The remaining chapters cover condensation, boiling heat transfer, and radiation. The last chapter of the book discusses various types of heat exchanger.

Although the material is well presented, some minor criticisms must be made for the benefit of those who desire to use the book for teaching purposes. The subject of non-uniform properties is omitted and, although the Fourier equation is given for the case of anisotropic bodies, it is not stated that it applies also to temperature-dependent thermal conductivity. Constancy is also implied in many parts of the text. Again, the solution of the heat-conduction problem in a rod is applied to extended surfaces, which is correct for straight fins, but incorrect for circular fins. This is perhaps an accidental lapse on the author's part. There is also some confusion between the terms "fin efficiency" and "fin effectiveness".

In the discussion on steady-state conduction, the author gives the graphical method of solution without its mathematical background or a mention of its limitations. Furthermore, when dealing with the numerical method of solving the conduction problem, the example given is ill-chosen, because it uses only a small temperature gradient. Moreover, the term "relaxation method" is applied wrongly to describe the type of solution given.

In the chapter on transient one-dimensional conduction, Schmidt's graphical method is presented without the author indicating that it is really a particular case of the general numerical solution and, once again, the limitations of the method are not given.

Apart from these minor disadvantages, which most teachers will be able to overcome readily, this book is a useful one and should help to bridge the gap between the very elementary treatises on the one hand, and the more specialised texts on the other.

Reactor Shielding Design Manual

Edited by T. Rockwell

McGraw-Hill Publishing Co., New York and London, 1957, 488 pp., 45s.

MANY current reactor studies are concerned with small highly-rated units employing enriched fuels and new developments in coolant and moderator. The fact that these studies are concerned with mobile application and, in particular, with marine propulsion lends added interest to the appearance of the U.S.A.E.C. Reactor Shielding Design Manual. This volume, edited by T. Rockwell and sponsored by the Naval Reactors Branch, summarises many earlier U.S. shielding reports and includes new data based on developments carried out for the *Nautilus* programme and for the pressurised-water reactor. The procedures required and practised for these reactors are different from other shielding applications and the present volume, while containing much of general value, is necessarily restricted in outlook. The ten chapters include sections on shielding theory, allowable radiation levels, the shielding of reactors and active fluid lines and the problems of access under shut-down conditions. So far as the chemical engineer is concerned, the book contains all the necessary information for the design of gamma shields for highly active chemical and waste-disposal plants. The philosophy of plant layout discussed in chapter five could, with reservation, be taken to cover active chemical processes, although the stated generalisations apply particularly to water-cooled reactor systems. The real problem in shielding is always to select a combination of materials giving maximum effectiveness for minimum cost. It is disappointing to find that the authors place little stress on this. The book tells us always how to design for minimum weight, but not necessarily for minimum expense. The remark made on p. 157, that "the same kinds of requirement for minimum shielding . . . which is so important to naval reactors also applies to large-scale stationary plants", is not necessarily true. Thus the methods of fabrication and installation shown in the book, while necessary for small shields, are expensive and are of quite limited general application.

One of the most difficult aspects of shield design arises from neutron and gamma streaming in slots or gaps and other irregularities, intentional or unavoidable in design. These problems are discussed in chapter eight in what is in many ways the best section of the book. The editor wisely draws attention to the preliminary nature of some of the data quoted but, cautiously used, it should simplify many shielding problems.

The book is a valuable addition to the sparse literature on shield design and is well presented with clear and accurate illustrations. For a reference volume, it is marred by a poor index and it would be worth while giving consideration to either reducing the size or splitting future editions into two volumes. A great improvement would be effected if the reference data, nomograms and graphs could be separated from the discussion, engineering design and derivation of equations. B.E.E.

Redgrave's Factories, Truck and Shops Acts, nineteenth edition

by J. Thompson and H. R. Rogers.

Butterworth & Co. (Publishers) Ltd., London, 1957, 1366 pp., 57s.6d.

ALTHOUGH this is a legal reference book, it is one that can be recommended to non-legal readers on account of its lucidity. The present authors are, respectively, one of Her Majesty's Counsel and an ex Deputy Chief Inspector of Factories and this has enabled a balance to be maintained. Stated briefly, the book covers the legal duty which an owner or occupier owes to the persons he has in his employ and also gives an annotated account of the various interpretations which the courts have given to the different aspects of this duty. The authors have adhered closely to their brief, and, usually, only the relevant parts of each Act are quoted. This provides the one flaw in this otherwise-excellent work. For the non-legal reader, a wider treatment of, say, the National Insurance (Industrial Injuries) Act of 1946 would have enhanced its value.

The book is planned in the usual form adopted for legal publications in that tables of statutes and cases are given and also tables showing how far the later Acts have repealed or re-enacted the provisions of earlier legislation. The reader who is interested in either industrial legislation or its impact on social history will find these tables very useful. They make very clear the periodic need for action by Parliament to remedy abuses.

The Factories Acts and the relevant Orders occupy the greater part of the book. The notes are so comprehensive that it seems unlikely that any incident could occur in which this book would fail to give an executive an accurate indication of his legal position. The same may be said of the section on the various Shops Acts. A.W.

Books Received

A History of Industrial Chemistry. By F. Sherwood Taylor, Ph.D., M.A., B.Sc. 467 pp., illustrated. 8½ × 5½ in. First edition. William Heinemann Ltd., 99 Great Russell Street, London, W.C.1, 1957. Price 30s.

Economics of Atomic Energy. By Mary Goldring, B.A. 179 pp., illustrated. 8½ × 5½ in. First edition. Butterworths Scientific Publications, 4 Bell Yard, London, W.C.2, 1957. Price 15s.

Men and Automation. By L. Landon Goodman. 286 pp., illustrated. 7 × 4½ in. First edition. Penguin Books Ltd., Harmondsworth, Middlesex, 1957. Price 3s. 6d.

New Books

Plant & Process Dynamic Characteristics

Proceedings of the 1956 Cambridge Conference, edited by THE SOCIETY OF INSTRUMENT TECHNOLOGY.

The papers contained in this volume are the results of the first attempt in this country to bring together for discussion those engaged in fundamental research on the dynamics of processes, the measurement and control specialists and those with practical experience of plant operation.

The proceedings of the conference, and the membership, were weighted in the direction of chemical engineering.

Contributions were invited from those actively engaged in these fields and who could report on new concepts, techniques or the results of practical plant tests.

Price 50*s.*

Economics of Atomic Energy

By MARY GOLDRING, B.A.

The second book in the 'Atoms for Peace Series' explains, in non-technical language, the impact of nuclear energy on society and discusses critically the effect of this new development on a country's economy; how far a country should want to establish an indigenous atomic industry, what prospects there are for atomic power; and what prospects for international trade in atomic plants and materials, how the industry is organised and administered and lastly, what Britain's role is and should be in the future of this new industry.

Price 15*s.*

Safety in the Chemical Laboratory

By H. A. J. PIETERS and J. W. CREYGHTON.

This thoroughly revised and enlarged second edition is designed as a handbook and guide for students and staffs of chemical laboratories describing precautions to be taken against the potential hazards connected with their work.

The inclusion of analytical methods and tables of data ensure that this International Safety Manual is useful to all chemists. To management it offers advice in organising the laboratory operations so that a maximum of safety can be achieved.

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Journal of Chemical Education

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Chemistry and Industry

Vapour Phase Chromatography

Edited by D. H. DESTY.

The papers contained in this volume are those presented at the 1956 London Symposium on Vapour Phase Chromatography. The thirty-five papers represent *nearly one-fifth of the total references available* on this promising new method of separation and analysis.

The discussions and nomenclature recommendations stimulate and inspire exploration into the fields of application for this new technique.

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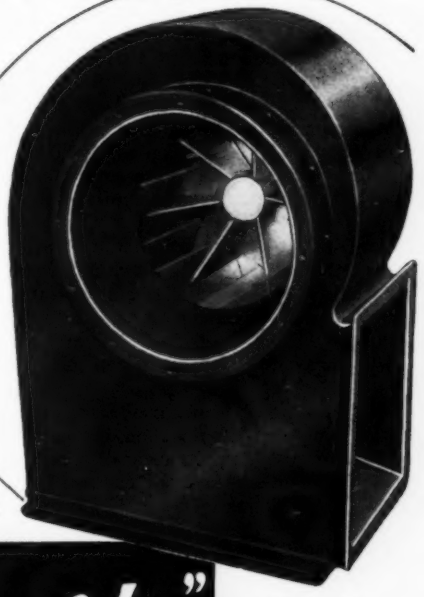

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Farbenfabriken Bayer

In 1956, Farbenfabriken Bayer's development programme for heavy chemicals, large-scale installations for organic intermediates, plastics and photo-chemical products reached a "temporary stage of completion", Dr. U. Haberland, chairman, told shareholders at the company's annual meeting at Leverkusen recently. Large sums, however, were spent on modernising the organic-dye plants at Leverkusen, and on the first development stage for the manufacture of titanium dioxide at Uerdingen. The group's turnover reached DM 1,596 million (£138 million) equivalent to an 11% rise since 1955. Sales on the home market rose by 7.6% and exports by 16.6%, reaching about 40% of the total turnover. With chemicals the rise in turnover was a little less than previously, but the export ratio remained unchanged. Trading barriers compelled the company to start production in foreign countries.

Swiss Chemical Expansion

Geigy's net profit for 1956 was SF 8.5 million (£692,000) compared with SF 8.1 million (£660,000) in 1955. The company's dyestuff exports increased over those in 1955 and the share of the European market, the company claims, increased at the expense of North America. Chemicals, textile finishing products and pharmaceuticals all showed increased turnovers but government restrictions in a number of countries had an unfavourable effect on the sales of insecticides. During the same year Ciba claimed to have increased their share of the world trade in chemical products. Turnover rose by 5.7% to SF 827 million (£66 million). As in previous years, 50% of the sales went to Europe and 40% to America.

O.E.E.C. Processing Plant

At a nuclear energy conference in Amsterdam recently, organised by the European Productivity Centre of O.E.E.C., it was announced that a study group set up in 1956 by 14 O.E.E.C. countries had come to the conclusion that a uranium processing plant should be established under the Organisation's auspices. The plant, it was recommended, should be able to treat a variety of fuel elements of natural and slightly-enriched uranium. The capacity for the first three or four years of operation (1961 to 1964) would not exceed about 100 tons annually.

Alabama Insecticide Plant

Construction has begun at Monsanto's Anniston, Alabama, site on new plant for producing Niran and methyl parathion insecticides. The area formerly occupied by the methyl parathion unit at Nitro, West Virginia, will be put to other use. The new plant will be integrated to chlorine and caustic supplies available at Anniston, and it is scheduled for completion late this autumn. It will be fully instrumented and each step in the methyl parathion process will be isolated as a precaution against the recurrence of a kind of explosion that was experienced recently at the Nitro plant.

Portuguese Fertiliser Production

The unusually high rainfall in 1956 enabled the hydroelectric companies in Portugal to supply the country's electrochemical industry with power for a longer period than usual. As a result, Amoniaco Portugues, S.A.R.L., for example, in 358 working days, produced 42,684 tons of ammonium sulphate as against 35,197 tons in 1955. When equipment for the production of ammonia using hydrogen from heavy petroleum is commissioned at the end of 1958, Amoniaco Portugues expects to be able to produce 70,000 tons of ammonium sulphate annually. The company has obtained authority to set up also plant for the production of ammonium nitrate.

American Natural Gas

The Federal Power Commission, which regulates the natural gas industry in the U.S.A., has approved plans of the Transcontinental Gas Pipe Line Corporation to expand its deliveries to the New York metropolitan area by some 83 million cubic feet of gas a day. To make this possible, the company is expanding its pipeline gas-gathering network in Texas by the addition of 247 miles of line.

Australian Titanium Expansion

Production of titanium oxide is to be greatly expanded at the Burnie, Tasmania, works of Australian Titan Products. The plant, started in 1949, was designed to produce 1800 tons a year. It is now producing almost 8000 tons a year, and extensions previously authorised should raise the production to 10,000 tons next year. The expansion now authorised will further increase the production to 20,000 tons a year.

Soviet Chemicals to Iran

Under a protocol signed recently between the Iranian and Soviet authorities concerning trade between Iran and the U.S.S.R., the quantity of Russian chemical products to be sent to Iran during the next three years is to increase from 2000 to 3000 tonnes.

Mexican Chemical Industry

Sulphuric acid plants in Mexico now number 13, with a total annual capacity of 194,000 metric tons compared with 63,145 tons in 1950. Production in 1956 was 161,483 tons and imports were 2628 tons. Consumption is expected to reach 240,000 tons in 1960 and at least three new plants are known to be planned to cope with this increased demand. Sosa de Mexico, a new company formed in Monterrey, expects, at the end of 1957, to commission plant to produce annually 6500 tons of chlorine, 7300 tons of rayon-grade caustic soda and 3000 tons of D.D.T.

Negev Phosphate

The establishment of an I.£2 million (£395,000) calcination plant for the enrichment of Negev phosphate was among the recommendations made by the Israeli Technological Advisory Board (a joint organisation of the Ministry of Development and the U.N. Technical Assistance Administration) at its first meeting recently.

New Synthetic Resin

Industrial production of the new synthetic resin, Moplen, elaborated by Montecatini by the polymerisation of propylene from oil, commenced recently at the company's Ferrara petro-chemical plant. The new resin, it is said, can withstand temperatures of up to 160°C, and it has great tensile strength.

Indian Lignite Deposits

The Geological Survey of India has nearly completed its survey of lignite deposits in the Kashmir valley and it is now engaged in a survey of copper, lead, gypsum, graphite, asbestos, chromite and limestone deposits in the valley. A survey of bauxite and coal deposits in Jammu Province will also be undertaken shortly.

Danish Pyrolytic Gas Works

The 90-metre high cracking tower of A. P. Moeller's pyrolytic gas works at Amager is to be rebuilt and the works will be out of production for a year. This will put a strain on Copenhagen's existing gas works at Valby, and will prevent the Danish Spirit Factories' ethylene spirit plant at Amager going into operation.

Dutch Carbohydrate Laboratory

A new laboratory of W. A. Scholten's Chemische Fabrieken N.V., Foxhol, devoted to the study of the chemistry of polymeric carbohydrates was opened by the Netherlands Minister of Economic Affairs recently. The new building houses complete paper and textile laboratories.

Norwegian Titanium Deposits

Deposits of titanium ore discovered at Jossingfjord, near Stavanger, are larger than was at first thought and are estimated to amount to 350 million tons. It is planned to set up an organisation to mine them with a capital of Kr. 75 million (£3,250,000).

Ceylon D.D.T.

The D.D.T. plant which was presented to Ceylon in 1952 by the UNICEF, on condition that it was operated to its full 700-tons-a-year capacity, has been returned to the donors, as costs of production are substantially above imported prices.

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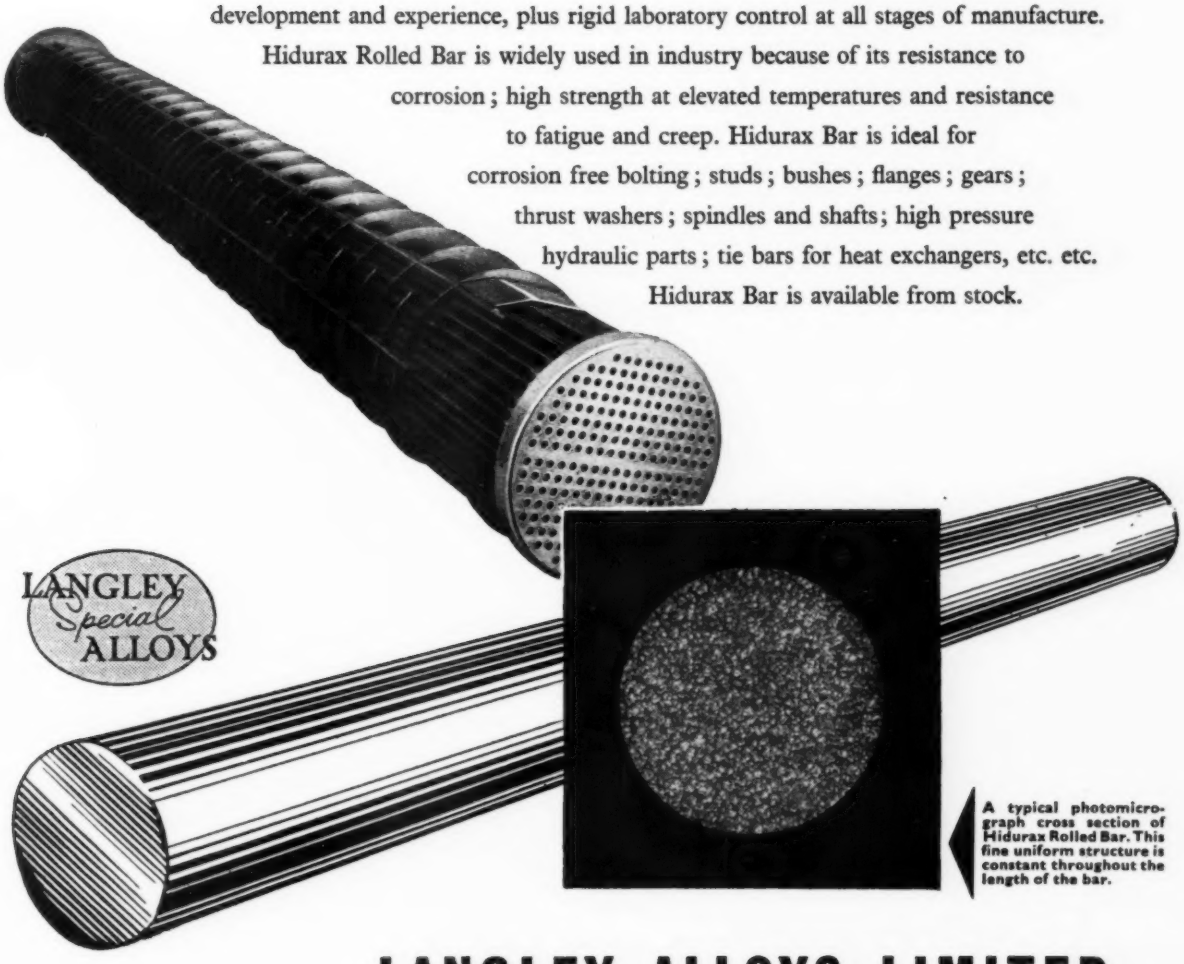

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PLANT EQUIPMENT NEWS

Horizontal Filters

Stockdale are now building Feinc horizontal rotary vacuum filters under licence from Filtration Engineers Inc., of Newark, New Jersey. The filters, which are specially suitable for easy filtering-materials where ample washing is required, are manufactured in a standard range of sizes from 3 ft to 12 ft in diameter. Special sizes can be made to specification, and modifications can be

incorporated to make the filter suitable for particular applications. The machines in the size range 3 ft to 8 ft are fitted with a centrally-mounted variable-speed drive installed in the base of the frame—an arrangement that enables the filters to be moved easily if desired. The larger sizes use a conventional spur gear with roller chain drive which, however, has a ball-type main bearing with a replaceable hardened race. **Stockdale Engineering Ltd., Poynton, Ches.**

BCE 1642 for further information

Differential Pressure Transducer

The new Evershed differential pressure transducer, type ER.125, converts differential pressures into an electric direct-current signal suitable for remote indication or as the measured value signal for an electronic process controller. Its output may also be employed as one of the input variables for the company's simple analogue computer. The instrument is suitable for use with oil, viscous or corrosive fluids, water, steam or gases, and its maximum temperature rating is 170°C. **Evershed & Vignoles Ltd., Acton Lane Works, London, W.4.**

BCE 1643 for further information

Bellows Pump

Crane Packing have developed a small pump for use with highly corrosive chemicals, in which all parts which come into contact with the fluid are made from fluon (polytetrafluoroethylene). The pump can handle, it is claimed, all the usually used chemicals and solvents, except fluorine and molten alkali metals, within the temperature and pressure ranges specified. In addition, it can also function successfully with liquids having solids in suspension, so long as they do not silt up the convolutions of the bellows or prevent the valves operating. The pump has been designed mainly for use in laboratories on short-term experiments, or as a metering pump providing an infinitely-variable flow over the delivery range. As a metering unit, an accuracy of ±2% has been maintained consistently in test runs. The pressure range is delivery 0 to 30 psi. **PTFE Engineering Division, Crane Packing Ltd., Slough.**

BCE 1644 for further information

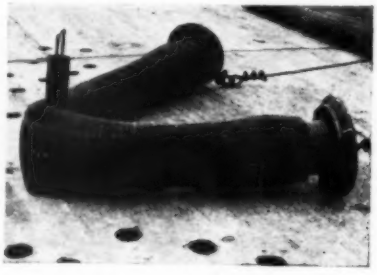
Direct-Reading Pyrometer

A pyrometer which shows the surface temperature of a hot body without correction being required for emissivity is among equipment available from Lands. The pyrometer head incorporates a concave gold-plated reflector. When this reflector is placed on a hot surface, the surface and its image in the reflector form the equivalent of a uniform temperature enclosure. **Land Pyrometers Ltd., Sheffield.**

BCE 1645 for further information

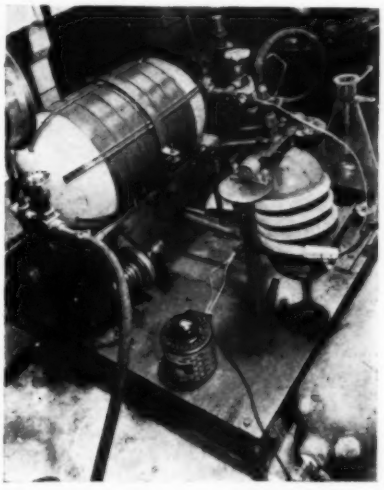
Neoprene Oil Hose

Dunlop have developed a neoprene oil-discharge hose which is only two-thirds of the weight of a conventional hose of the same bore and working pressure. Yet it is soft-walled and is constructed without coils of solid steel wire and, the makers claim, it is highly resistant to damage by kinking or rough usage. It is designed so that the tendency to distortion when under pressure can be controlled within fine limits. At a full working pressure, for example, there is a



maximum increase in length of 2%. A prototype has been subjected to sharp kinking and release for 1000 cycles without showing any sign of failure or distress. When it was then pressurised, it stood up to a pressure of more than 1000 psi without failure. **Dunlop Rubber Co. Ltd., St. James's House, St. James's Street, London, S.W.1.**

BCE 1646 for further information



Cuttable Heating Tape

Heat-by-the-Yard is an elastic heating tape which may be cut from a dispenser to any length. The voltage required to obtain a certain temperature for a given length, may be obtained from a nomogram. The product consists of a continuous network of resistance wires enclosed in a knitted elastic sleeve of glass fibre yarn, and it is made in ½-in. and 1-in. widths. **Electrothermal Engineering Ltd., 270 Neville Road, London, E.7.**

BCE 1647 for further information

Smoke Alarm

Lancashire Dynamo are making available a smoke alarm and indicator on which patents are pending for its circuit arrangements. Basically, it consists of a light projector unit, a photo-electric receiver unit and a main control unit. It is built to comply with B.S.S. Nos. 2740, 1956, and 2811, 1957. A small indicator meter is included for calibration, and the unit is arranged to operate with an external indicator meter or recorder where observation or recording of the smoke density is required. The light projector unit and the photo-electric receiver unit are of substantial cast-iron construction and are weatherproof. The equipment is designed for operation with a light beam throw from 1 to 20 ft, and the light projector and photo-electric receiver unit will operate in ambient temperatures up to 135°F. The apparatus will work satisfactorily for a plus 10% minus 15% mains supply voltage variation.

The company has just extended its range of variable-speed drives to include equipment (series FMC.1) suitable for fractional horse-power motors of rating 1/20th h.p. or less. It is designed to provide a 5:1 speed range by armature-voltage variation, with constant torque over this range. For certain applications, a speed range of 10 : 1 or greater may

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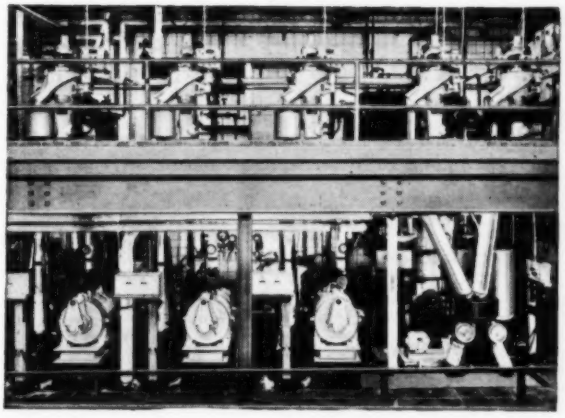

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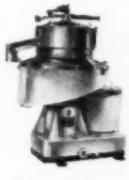
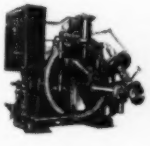
D-2 Centrifuge



DG-2 Autojector

DV-2 Centrifuge



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PLANT EQUIPMENT NEWS

be used. The adjustable d.c. supply for the armature of the motor is provided by a thyratron rectifier, this forming part of a closed-loop speed regulator system. A fixed field supply is also provided from the control unit. **Lancashire Dynamo Electronic Products Ltd., Rugeley, Staffs.**

BCE 1648 for further information

Pressure Switches

Nash & Thompson are making a new range of pressure-controlled switches. They are available in three models, covering a range of 0.15 psi to 75 psi, are of simple construction and can be supplied with a tapped connection which enables them to be used as differential switches on pneumatic circuits. The company is also making two of their flow-controlled electrical switches flame-

proofed to Buxton certificate standard for gases in groups 1, 2 and 3. **Nash & Thompson Ltd., Oakcroft Road, Chessington, Surrey.**

BCE 1649 for further information

Research Photographic Flash

Model 5/20A short-duration flash unit has been developed by Ernest Turner for research photography and the analysis of movement by photographic means. It provides two identical short-duration flash discharge light sources which can be operated independently, simultaneously or consecutively with a known delay. The delay is adjustable and is calibrated from 10 microseconds to 10 milliseconds. A flash energy of either 5 or 20 joules can be used in both lamps by operating a selector switch. The instrument, it is said, combines the high photographic efficiency of xenon with a very short flash duration and complete stability, and it works from a mains supply. **Ernest Turner Electrical Instruments Ltd., High Wycombe, Bucks.**

BCE 1650 for further information

Spray Gun

A spray gun for use with preparations which should not be subjected to violent agitation and change of direction of flow, or which cannot be removed readily from the spraying equipment, has been designed by Alfred Bullows. The gun's fluid-passage is a straight tube, normally of stainless steel. Any material which can be machined may be used for this part,

however, and the equipment can be adapted, therefore, for use with a range of highly corrosive, abrasive and other difficult fluids. **Alfred Bullows & Sons Ltd., Long Street, Walsall.**

BCE 1651 for further information

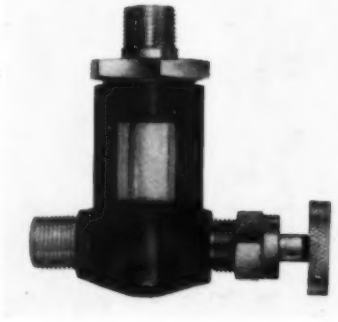
Agitator Drives

Stockdale are now manufacturing a new range of agitator drives which are said to be the first gear units to be designed and manufactured in Great Britain for driving both vertical and side-entering, permanently-mounted agitators. For the horse-power for which a given size of drive is designed to transmit, the output shaft is 50% larger in diameter than a similar shaft in a typical standard gear unit, and the bearing centres are more than 50% greater than on a standard gearbox. This results in a drive which can be direct-coupled to an agitator shaft of considerable unsupported length. The drives are suitable for installation on open tanks and vats and in closed pressure vessels, and they can be used on tanks up to 20 ft deep. **Stockdale Engineering Ltd., Poynton, Ches.**

BCE 1652 for further information

Feed Indicator

Liquid Systems have developed a double-window sight-feed indicator having an adjustable flow. The two windows allow the size of the liquid stream to be observed from either side of the instrument, and fine control of the amount of liquid discharge is made possible by the use of a port-hole regulator and a needle valve having a very fine thread. The standard size of indicator is for ¼-in. B.S.P.



inlet and outlet, but other sizes are available. **Liquid Systems Ltd., Union Road, Croydon, Surrey.**

BCE 1653 for further information

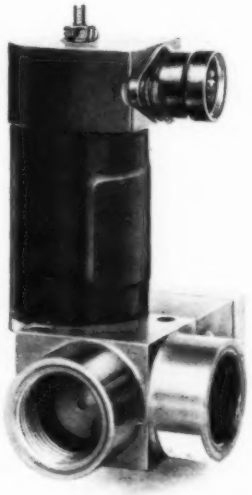
Grinder Control

A device for maintaining a grinder loaded to optimum capacity continuously is being produced by the 30-98 Co. It incorporates a timing apparatus so arranged that, when the grinder-motor power is below maximum, the feed is increased in steps with a waiting period in between to allow the increased feed to register its full effect on the power. Should an overload occur, the feed is decreased steadily with no waiting periods until the power has fallen below the control point. The amount of increase of feed at each step, the length of the waiting period and the rate of decrease of feed can be varied to suit the operating conditions of a particular installation. By employing different current transformers, one instrument can be used for the range from 10 to 400 h.p. **The 30-98 Co. Ltd., Gatwick House, Lowfield Heath, Surrey.**

BCE 1654 for further information

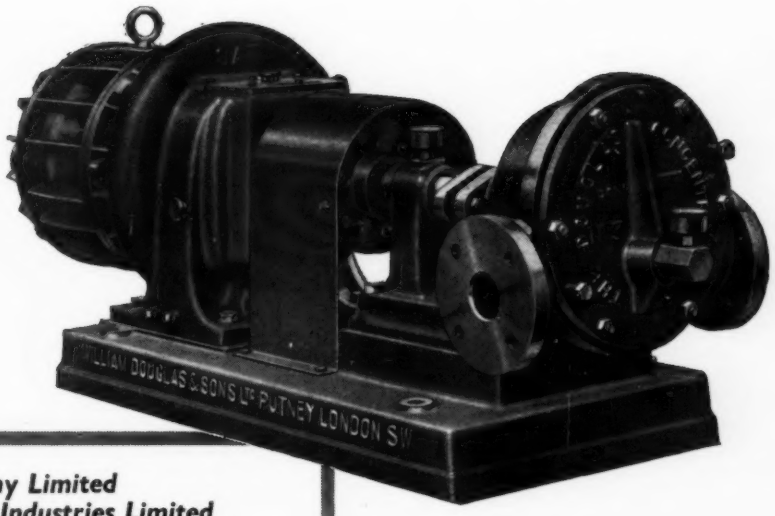
Hot-air Valve

Hymatic are adding a hot-air electro-pneumatic stop valve, type MD.32, to



their range of pneumatic equipment. Although it has been specially developed for aircraft use, its specification makes it suitable for all types of pneumatic system, the makers say. With a thermal range from −40°C ambient to +365°C, the valve can be kept continuously energised at the highest temperatures. Rated at 24 volts, it consumes 0.61 amps at 20°C. It is fitted with ¼-in. B.S.P. connections. When the solenoid is energised, air from the upstream side of the valve is allowed to pass through a pilot valve on to the rear face of a piston of larger area than the valve poppet, thus opening the valve. It is closed by shutting off the flow of upstream air to the piston. Residual air bleeds past the piston clearance

Britain's Busiest Pump



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to the spring chamber, which is vented to atmosphere. **The Hymatic Engineering Co. Ltd., Redditch, Worcs.**

BCE 1655 for further information

Dispersing Unit

The Dispersitron, a mechanical dispersing unit, will shortly be made and placed on the market in the British Commonwealth by George Scott, as the result of an agreement reached between themselves and Professor P. Willems, of Lucerne, Switzerland. The machine is suitable for use in processes employed in the chemical, paper, food, paint, pharmaceutical and cosmetic industries. **George Scott & Son (London) Ltd., Artillery House, Artillery Row, London, S.W.1.**

BCE 1656 for further information

Automatic Analysis

Continuous analysis of a chemical process during manufacture is undertaken by the Titromatic analyser, recently made available by Electronic Instruments. The apparatus is connected to the main plant stream and at regular intervals a measured quantity of the solution being manufactured is fed to a reaction vessel. After dilution with water, titration with a standard reagent takes place. The amount of reagent used is determined by an electrical device which seeks and finds the level of the reagent, and records the volume used on a chart. In the meantime, the reaction vessel is being emptied and the whole process starts again. **Electronic Instruments Ltd., Lower Mortlake Road, Richmond, Surrey.**

BCE 1657 for further information

Proportioning Temperature Indicator

A novel proportioning temperature indicator and controller has been introduced by Technical-Equipment-Services. The proportioning band may be readily adjusted to suit the heat supply and demand conditions, and the equipment is available to suit various temperature ranges from sub-zero to over 250°C. The instrument embodies a liquid-filled bulb, capillary and bellows, and the new proportioning system consists of a thermoelectric unit. The temperature hunting effect usually associated with an on-off controller is buffered by the action of the electrothermal unit, and temperature overshoot and undershoot is said to be eliminated. Provision is made for adjusting the degree of proportioning between the limits of narrow and broad. **Technical-Equipment-Services, 43 Satanita Road, Westcliff-on-Sea, Essex.**

BCE 1658 for further information

Centrifugal Pumps

The Seal range of centrifugal pumps recently introduced by Girdlestone has an arrangement of the mechanical seal which, it is said, provides the following advantages: (*a*) complete cooling of the seal is assured by the liquid pumped without resort to flushing pipes; (*b*) the large internal liquid-area prevents settlement of suspended or foreign matter around seal; (*c*) replacement of seal involves only the removal of the suction end-cover and impeller. The pumps, comprising volute, impeller, suction end-cover and mechanical seal, are available with delivery connections in five sizes from ¾ in. to 1½ in. and they can be bolted directly to engines or machines provided with suitable spigot and shaft extension, or to the flanged end-shield of an electric motor forming a motor-pump unit. **Girdlestone Pumps Ltd., Woodbridge, Suffolk.**

BCE 1659 for further information

Air Barrier Mask

Production of an industrial protective mask which makes use of a barrier of compressed air was commenced by R.F.D. recently. In operation, clean air under pressure continually enters the hood of the mask and exhausts through a vision opening, thus setting up the barrier. The masks are specially suitable for use in paint and metal spraying and in other operations where ordinary face shields or goggles would quickly become fouled. The hoods are expendable—at first they are being made in translucent polythene, but later they may also be supplied in paper and cloth. A regulating valve enables the operator to control the air pressure and allows the mask to be supplied from a spray-gun air-supply hose if required. **R.F.D. Co. Ltd., Godalming, Surrey.**

BCE 1660 for further information

Reinforcing Fabric

A new rotproof fabric woven from glass and designed for use as a reinforcing membrane for coal tar and asphalt compounds used in waterproofing and anti-corrosion applications is now being produced by Fothergill & Harvey. The fabric, known as Tygascrim, is an open-weave fabric weighing 2.2 oz. a square yard. Its tensile strength is 75 lb. an inch in both warp and weft directions and its bursting strength 140 lb. a sq. in. It is available with two types of coating—balanced asphalt-resin combination or a coal-tar binder. **Fothergill & Harvey (Sales) Ltd., Harvester House, Peter Street, Manchester.**

BCE 1661 for further information

Benzole-vapour Meter

A benzole meter using ultra-violet light, designed to give a rapid and accurate measurement of the amount of benzole present in rich coal gas, or left in the gas after the extraction process, has been developed by Hanovia in conjunction with the research department of National Benzole. The meter will measure 0.1 to 6 g. of benzole per 100 l. of coal gas, but it can be adjusted when required to show a full-scale reading for 4 g./l. of gas. It will respond almost identically to benzene, toluene or xylene, and will also respond in varying degrees to other important vapours with high absorption in the u.v. region around 2.537 A.U. The operation of the unit depends on the characteristic absorption values of certain organic and inorganic compounds in vapour form to selected ultra-violet

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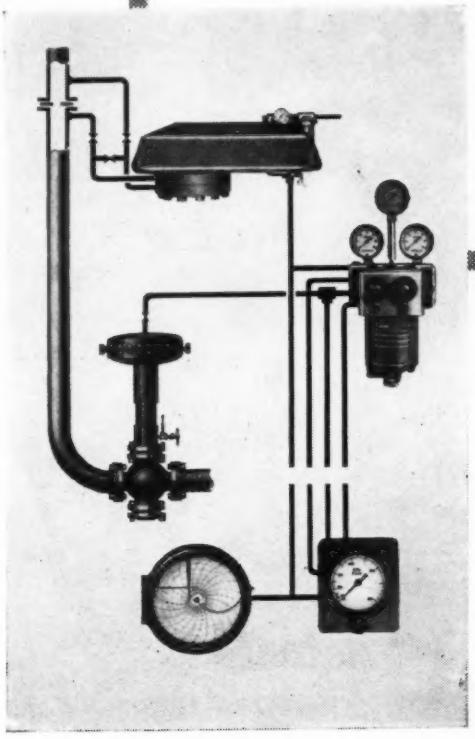

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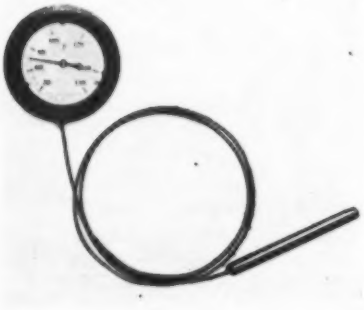
wavelengths. The instrument comprises a sensitive photo-electric photometer in which a fixed-length gas cell is interposed between a low-pressure mercury vapour tube—substantially monochromatic—and a photo-electric detector with a quartz envelope. The photo-electric cell is arranged to unbalance a dual-pentode bridge circuit when the transmission path is influenced by the presence of benzole. The meter mounted on the front panel indicates the state of unbalance in the bridge circuit and thus the amount of benzole in the chamber. **Hanovia, Slough, Bucks.**

BCE 1662 for further information

Thermometers in Plastic

A plastic thermometer has been designed by Tool Treatments specially for use in plating and other processes in which thermometers are normally exposed to steam, acids or other corrosive fumes. The instrument is fitted with a 4-in. dial housed in a Bakelite case with screw-on front, and the 6-ft capillary tube is plastic covered. The instruments have a working



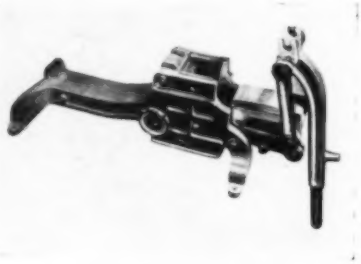
range of from 30 to 150°F. The company has also introduced in polythene a 5-gallon stacking bin and, in high-density rigid polythene, a 10-gallon stacking bin and a 2½-gallon bucket. **Tool Treatments (Chemicals) Ltd., Colliery Road, Birmingham Road, West Bromwich, Staffs.**

BCE 1663 for further information

Breast-battery Lighting Set

A breast-battery lighting set, which has been certified by the Ministry of Labour and National Service as intrinsically safe for use in inflammable atmospheres, is now available from G.E.C. The makers state that it was developed in collaboration with a large petroleum company and, although designed primarily for use in the oil industry, it has a wide application to industry in general. The battery container, of tough moulded Neoprene, is waterproof, impervious to oil or petroleum and fire-resistant. The total weight of the set, including three 1.5-volt cells, is just under 3½ lb. **The General Electric Co. Ltd., Magnet House, London, W.C.2.**

BCE 1664 for further information



Hand Jaw-crusher

A light-weight, hand-operated jaw-crusher designed to deal with small samples of rock, ore, etc., has been introduced by Knapp & Bates. In its construction, aluminium alloy has been used wherever possible and the crusher can be carried easily by one man. It has an output of 40-45 lb./hr when reducing material from 1½ in. cube to ¼ in. The two jaws are of manganese steel. Risk of loss by flying particles has been eliminated, the makers say. **Knapp & Bates Ltd., Africa House, London, W.C.2.**

BCE 1665 for further information

Electro-magnetic Clutch

The sales development and manufacture of the magnetic clutch and couplings elaborated by Autronic has been taken over by Newport Instruments. The clutch consists of only three components: a disc magnet, a disc armature, and a floating plate between them and in contact with both. The magnet and the armature are of steel alloy with their opposing faces highly polished and hardened, and the separating plate is made of soft iron alloy with high magnetic permeability. Low voltage (12 or 24 volts) direct current is conducted to the windings of the revolving armature through hard copper-graphite brushes. When the current is applied, the magnetic flux between armature and magnet builds up to constitute a powerful linking force between the three components—the lines of force being conducted through the plate. The 1-in. diameter clutch will transmit torque at 30 in./lb. with a 0.35-amp loading, and the 3¼-in. diameter model has a static torque of 210 in./lb. at 0.9 amp. New applications for the clutch are continually being discovered it is said, their use in digital computers being an indication of their future potentialities. **Newport Instruments (Scientific & Mobile) Ltd., Newport Pagnell, Bucks.**

BCE 1666 for further information

Small Loading Shovel

Now in quantity production by Weatherill is a new small S.1 mobile industrial loading shovel. It is of only 4 ft 6 in. width and 4 ft 9 in. wheelbase, and it can be operated under a ceiling as low as 6 ft. 3 in. These features, the makers point out, make the machine very manœuvrable. It has a half-ton lifting capacity and is said to achieve a very high output, especially when handling materials such as sugar, salt, fertilisers, oxide and glass. Operator comfort and safety have received special attention. **F. E. Weatherill Ltd., Welwyn Garden City, Herts.**

BCE 1667 for further information

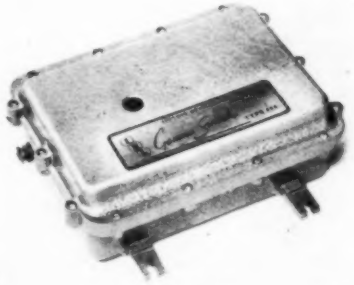
Pressurised Fire Extinguisher

A new pressurised fire extinguisher of the vaporising-liquid type has been developed by Pyrene. A squeeze-grip release valve makes it readily usable with one hand. It is charged with one quart of either Pyrene fire extinguisher liquid or chlorobromomethane (CB). Both liquids form a heavy vapour on reaching a temperature of 200°F, and they are effective against all fire outbreaks involving motor vehicles and small petrol, paraffin or alcohol fires, the makers state. They may also be used with safety against outbreaks involving electrical apparatus. A pressure gauge is fitted. **The Pyrene Co. Ltd., 9 Grosvenor Gardens, London, S.W.1.**

BCE 1668 for further information

Process Control by Nucleonics

The GammaSwitch is a simple process-control device based on radiation detection, and it is said to be the first of its kind. Level control, density and liquid



interface detection and flow-failure detection are among the kinds of control which can be effected with its use. In, for example, the control of high and low levels of material in a hopper, a switch is mounted at the appropriate level outside the hopper and a gamma-ray source (suitably enclosed) is mounted on the opposite side. If the relay is set to trip when the radiation penetrating the hopper changes by the amount absorbed by the material in the hopper, a warning light or buzzer can be operated by the switch whenever the material passes the predetermined level. Alternatively, the switch can be connected to the device controlling the supply of material to the hopper, thus providing automatic control. **Isotope Developments Ltd., Beenham Grange, Aldermaston Wharf, nr. Reading.**

BCE 1669 for further information

New Relief Valves

A range of relief valves, developed by Megator originally for use with the company's pumps, is now being made generally available to industry. A special feature of the products is that the clack

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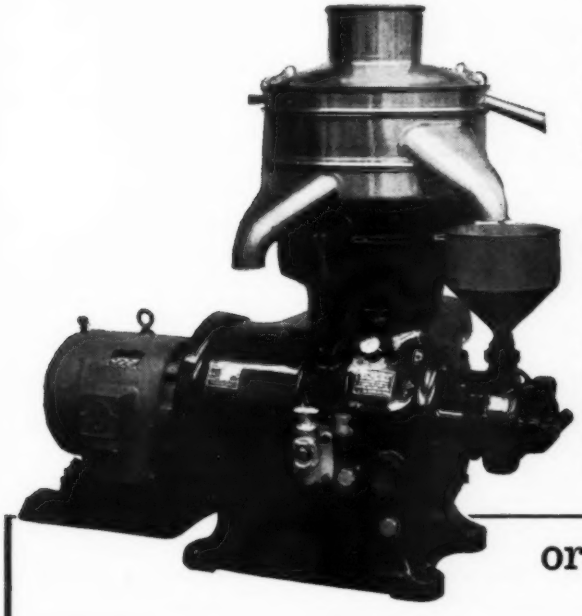

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Better taste and smell, and consequently a fat that commands a **Higher price**
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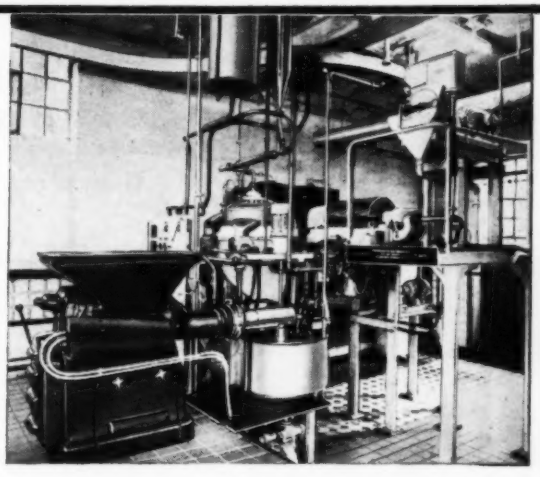

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is fitted with a skirt. As soon as the valve begins to open the skirt presents a greater area to take the pressure, and this, the makers say, makes the valve more positive and stable in action. Each valve is fitted also with an arrangement to render more difficult any unauthorised interference with the setting. The standard sizes of the valves are 1 in., 1½ in., 2 in. and 3 in., and these cover the setting range 65-150 psi. **Megator Pumps & Compressors Ltd., 43 Berkeley Square, London, W.1.**

BCE 1670 for further information

Smoke-density Indicator

The Hackbridge smoke-density indicator, type No. 2/SDL, has been designed to measure, at any instant, the density of smoke being emitted by chimney stacks and flues. Its calibration is related to the Ringelmann chart, and the instrument may be made to give an audible or flashing warning when a dangerous level of density has been reached. A pen recorder may also be included for logging over long periods the number of times that black smoke is emitted and the duration of the emissions. The equipment consists of a light source which transmits a parallel beam of light across the inside diameter of the chimney stack or flue to which it is attached, the beam falling on a photo-electric receiver arranged diametrically opposite to the light source and at the same level. **Hackbridge & Hewittic Electric Co. Ltd., Walton-on-Thames, Surrey.**

BCE 1671 for further information

Constant-feed Scale

Avery announced that, after considerable development, they are making their constant-rate feed-scale generally available. It is produced in two sizes. The smaller is equipped with a scale of 1 cwt. capacity, having a chart graduated to 4 oz. light and heavy by divisions of ¼ oz., enabling a very accurate control to be maintained. The feed gate is 6 in. wide and has a maximum opening of 2 in. In the larger machine the chart is graduated to 1 lb. light and heavy by divisions of 1 oz. The feed gate is 12 in. wide and has a maximum opening of 4 in. With both machines, the weighing belt-conveyor, with its associated motor and driving gear, is mounted as a self-contained unit on the weighing system. **W. & T. Avery Ltd., Soho Foundry, Birmingham, 40.**

BCE 1672 for further information

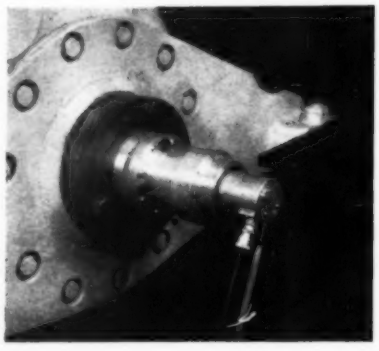
A Hand Drill

Pneumatic Tools have developed a new version of their C.P.9 hand drill specially for operation in confined spaces. The new tool is fitted with an offset handle which reduces the overall length to 11¾ in. The weight is 7½ lb. **The Consolidated Pneumatic Tool Co. Ltd., 4 Church Court, Richmond, Surrey.**

BCE 1673 for further information

Vibration Pick-up

Southern Instruments have made available a new torsional vibration pick-up, No. G218. It is a seismic type of instru-



ment and can be used to measure the amplitude of torsional oscillation or cyclic variation at the free end of a shaft. The pick-up contains a variable-inductance sensing element which detects the angular displacement between the fixing flange of the pick-up and a seismic inertia mounted within the unit. A permanent magnet supplies the damping and restoring forces and the instrument can be calibrated when mounted in its test position. It can be used on shafts which are oscillating as well as those which are rotating continuously. **Southern Instruments Ltd., Frimley Road, Camberley, Surrey.**

BCE 1674 for further information

Chromium-Molybdenum Electrodes

Three new chromium - molybdenum bearing electrodes which deposit weld metal of greater creep-resistance and corrosion-resistance than normal mild-steel electrodes are now being manufactured by Quasi-Arc. They are known as 1% chromium, ½% molybdenum; 2¼% chromium, 1% molybdenum; and 4/6% chromium, ½% molybdenum; and they have been specially designed for applications for each type of alloy steel. **Quasi-Arc Ltd., Bilston, Staffs.**

BCE 1675 for further information

Coolant Separator

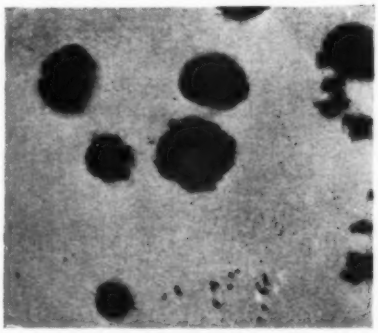
The new coolant separator being made by Rapid Magnetic Machines is said to

be the first all-British machine of its kind. It is designed to remove magnetic impurities from suds and other coolants. The contaminated liquid is fed through a restricted area between the separator housing and the stainless-steel cover of the magnetic drum. The drum is energised by permanent magnets fitted around its periphery and it rotates in the opposite direction to the flow of liquid. **Rapid Magnetic Machines Ltd., Lombard Street, Birmingham, 12.**

BCE 1676 for further information

Nodular Iron

Allis-Chalmers have developed a new process for the production of nodular iron. It involves, they state, the addition of salts to molten iron and it has been elaborated as a result of a five-year research programme conducted by the company. The method is patented, but it may eventually be made available to other organisations under a licensing agreement. Allis-Chalmers claim that the metal is about three times as strong as grey iron, yet it machines easily. At present the iron is being used in earth-moving equipment, of which the dis-

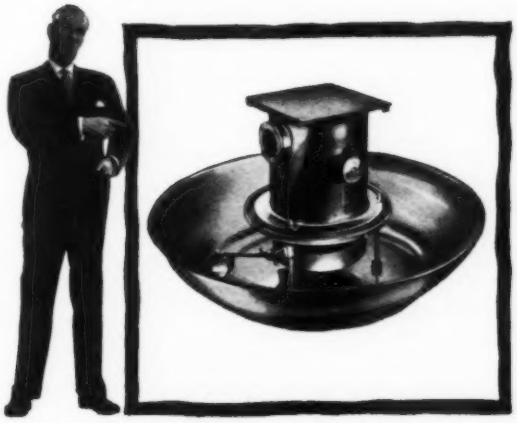


tributors are **Mackay Industrial Equipment Ltd., Faggs Road, Feltham, Middlesex.**

BCE 1677 for further information

BCE 1607 for further information

Do you KNOW?



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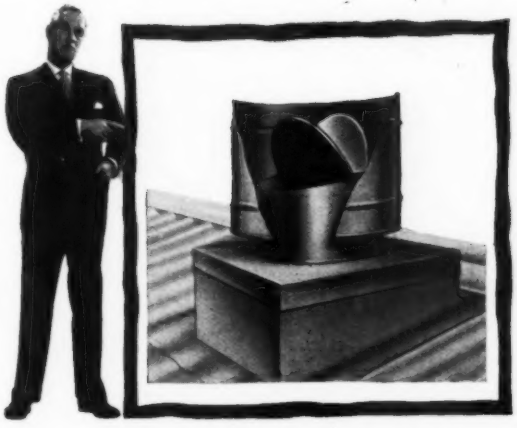

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An 'all-the-year-round' roof unit—the most powerful ventilator ever devised for the dispersal of fumes and vitiated air. Air movements range from 2,000 to 27,000 cu. ft. per minute. When not in use, the automatic stainless steel shutters keep valuable heat in and the elements out. Full details on request.

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BCE 1608 for further information

Adequate support

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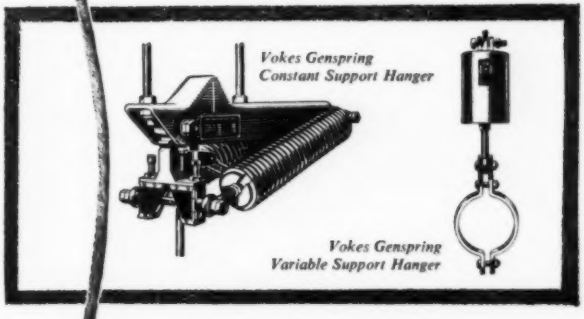
Vokes Genspring Constant Support Hangers are scientifically designed and constructed, compact, and provide constant support to a load of up to 30,000 lbs., over a range of movement of up to 12".

Where less accurate control of stresses is acceptable the Vokes Genspring Variable-Support Hanger compensates for vertical movement. With rated loads up to 5,418 lbs. they give a wide selection of support up to a maximum of 6" spring deflection.

Vokes Non-Resonant Sway Braces are designed to eliminate shock or vibration on steam lines, exhaust lines, compressor lines and similar applications. Sway Braces are supplied in nine different sizes, with initial loading range 92—1,500 lbs.



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SUSPENSION SYSTEMS

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VG/17a

PLANT EQUIPMENT NEWS

Other Items of Interest

Corrosion Ltd. have introduced Glocrete Stucco silicone, an improved version of their synthetic rubber-based paint, for outdoor masonry surfaces. The material now contains silicones. **Corrosion Ltd., 16 Gloucester Place, London, W.1.**

BCE 1678 for further information

Speedifix Strap-Seal tape is a self-adhesive tape suitable for use with heavy objects. It is made on a waterproof vinyl base to which is fused a continuous layer of reinforced rayon yarn threads, and these, in turn, are impregnated with a strong adhesive which grips to a wide variety of surfaces. The breaking strain of the product is not less than 180 lb. per inch width. **Industrial Tapes Ltd., Speedfix House, 142 Old Street, London, E.C.4.**

BCE 1679 for further information

A new plastic material manufactured by combining Velbex flexible P.V.C. with Terylene polyester fibre is being made by **Plastics Ltd., Higham Station Avenue, London, E.4.**

BCE 1680 for further information

A single-pan Ultramatic balance is now available from Stanton. It possesses a large, easily accessible pan; the weight-loading dials are compactly arranged and the weighing time for an object of unknown weight is said to be less than 30 seconds. **Stanton Instruments Ltd., 119 Oxford Street, London, W.1.**

BCE 1681 for further information

V-belts constructed with grommets totally enclosed in rubber to give, it is claimed, lateral flexibility to the belts are being made available by **Frank Wigglesworth & Co. Ltd., Shipley, Yorks.**

BCE 1682 for further information

Kenilworths new Hermetal Double-Bond plastic filler is manufactured from chemically-active, epoxide-based resins and forms a self-setting, solvent-free spreadable compound which is safe and non-injurious. It is available in two forms —as putty or cream. **The Kenilworth Manufacturing Co. Ltd., West Drayton, Middx.**

BCE 1683 for further information

The Hardex expander tool has been designed by A.A. Tools to provide a simple and speedy method of joining all standard copper tubes. It is said to be indestructible and capable of giving years of service. **A.A. Tools, 197a Whiteacre Road, Ashton-under-Lyne.**

BCE 1684 for further information

Panorama are making a nylon protective spectacle, model 956, for use by operatives in industry. It weighs ½ oz. and is said to give complete protection of the eyes to all wearers. The "lenses" are produced in either acetate or perspex plastic. For furnace inspection the model can be supplied with bi-coloured lenses, with or without ventilation holes in the side shields. **Panorama Equipment Ltd., 29 Seymour Mews, London, W.1.**

BCE 1685 for further information

Montgomerie Reid's new Tunstack battery-operated fork-lift truck is available in two versions, TS2 and TS3, having capacities of respectively one ton and 3000 lb. at 20-in. centres. The principal safety features of the machines are automatic power cut-out switches which operate when there is any danger of the trucks being misused. The standard lift is 108 in., but lifts up to 144 in. can be supplied to order. It is marketed by **G. Hunter (London) Ltd., 80 Fenchurch Street, London, E.C.3.**

BCE 1686 for further information

Hoover have made available a new range of drip-proof, squirrel-cage, induction fractional horse-power motors. They are constructed with aluminium-alloy end-frames of ample wall thickness and with generous strengthening ribs. Their white-metal sleeve bearings are machined concentrically to the end-frame register to aid alignment throughout. **Hoover Ltd., Industrial Products Department, Cambuslang, Lanarkshire.**

BCE 1687 for further information

C.2 Polysar asbestos clothing is now being used in the Heat Transfer Department of the Research and Development Branch of U.K.A.E.A. to protect process workers against liquid sodium splashes. **Bell's Asbestos & Enginering Ltd., Bestobell Works, Slough, Bucks.**

BCE 1688 for further information

A prototype assembly of an automatic weight control apparatus for free-flowing solids has been elaborated by S. Parsons. The weighing mechanism is a system of levers with a standard dial movement. **S. Parsons & Co. Ltd., Young Street, Bradford, 8.**

BCE 1689 for further information

Crompton Parkinson announce a newly-developed range of portable moving-coil ammeters and voltmeters which, they believe, are the first portable instruments available having circular scales and spring-mounted, sapphire jewel bearing, shock-resisting movements. The instruments have scales subtending 240°, 11 in. in length. **Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2.**

BCE 1690 for further information

The new Mark V portable Deminrolit plant supplies up to six gallons of pure water hourly. It is portable and embodies a dial-type conductivity tester. **The Permutit Co. Ltd., Permutit House Gunnersbury Avenue, London, W.4.**

BCE 1691 for further information

Industrial Tapes have developed Speedfix double-sided tapes, having both sides coated with adhesive, for use in machine shops. The tapes are rolled up with an interleaving uncoated strip which is peeled off and discarded in use. **Industrial Tapes Ltd., Speedfix House, 142 Old Street, London, E.C.1.**

BCE 1692 for further information

New Publications

A new 16-page catalogue dealing with chipping, caulking and scaling hammers has been issued by Consolidated Pneumatic Tools. It is the fifth in the series dealing with the company's air-powered industrial tools. Consolidated Pneumatic Tool Co. Ltd., 232 Dawes Road, London, S.W.6.

BCE 1693 for further information

Publication 159/557, issued recently by Kent, describes new equipment and modifications to existing equipment for use with pneumatic controls. George Kent Ltd., Luton, Beds.

BCE 1694 for further information

An illustrated list describing Evershed & Vignoles' range of transmitters for the measurement of air and gas differential pressures and flows has just been issued. It gives a general description of the flow transmitter and power unit as well as specifications, fixing details and maintenance data. A leaflet dealing with their new pressure transmitter ER.125, suitable for including in a file, is also available from the company. Evershed & Vignoles Ltd., Acton Lane Works, Chiswick, London, W.4.

BCE 1695 for further information

Wynn's latest technical bulletin, reference D.4, describes the company's patent straight-through diaphragm valve which is shortly to be made available. Wynn (Valves) Ltd., Granville Street, Birmingham, 1.

BCE 1696 for further information

A range of Hackbridge's transformers from 100 watts load to the largest forced-cooled transformers is the subject of a series of three publications that has just been made available. Hackbridge & Hewittic Electric Co. Ltd., Walton-on-Thames, Surrey.

BCE 1697 for further information

A folder in colour has been published by G.W.B. describing their packaged automatic boilers. The method of operation of their Voriflow gas burner is indicated by diagrams. G.W.B. Furnaces Ltd. (Boiler Division), P.O. Box No. 4, Dibdale Works, Dudley, Worcs.

BCE 1698 for further information

A revised edition of Liljeholmens' booklet, "An introduction to Amides, Nitriles, Amines and Quarternary Ammonium Salts", is now obtainable from Guest Industrials Ltd., 81 Gracechurch Street, London, E.C.3.

BCE 1699 for further information

Baldwins have recently published a comprehensive catalogue describing their range of pneumatic and low-pressure hydraulic equipment. This contains full details of power cylinders, control valves, pilot valves and various accessories. Copies from Baldwin Instrument Co. Ltd., Brooklands Works, Dartford, Kent.

BCE 1700 for further information

The latest Foster publication covers the theory and practical aspects and lists the products manufactured by the company for use in resistance thermometry. Foster Instrument Co. Ltd., Letchworth, Herts.

BCE 1701 for further information

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Month's News in Brief

Tower Works, the new head office and works of Sharples Centrifuges Ltd. at Camberley, Surrey, were officially opened recently by Mr. J. J. Serrell, president of Sharples' overseas group. The premises accommodate the production, planning, technical and sales divisions of the company; and the factory area includes a pilot plant, laboratory and a test bay linked with a glass-enclosed tower, designed to hold tanks used for development purposes, in addition to the factory floor. The internal transport of the factory is entirely mechanised, and the establishment employs about 100 people. Equipment for the home and overseas markets will be supplied from the new works.

Head Wrightson Processes announce that they have been awarded a contract by the Danish Atomic Energy Commission for the design, engineering, procurement and erection supervision of a materials-testing reactor similar to those they are now building for the U.K.A.E.A. at Harwell and Dounreay. It is planned that the reactor will be completed before the end of 1959.

Foster Wheeler have designed and engineered a crude oil distillation unit, a decarbonising unit and a fluid catalytic cracking unit and gas-recovery unit for the new Caltex oil refinery at Visakhapatnam, India. They were also responsible for the engineering of a polymerisation unit.

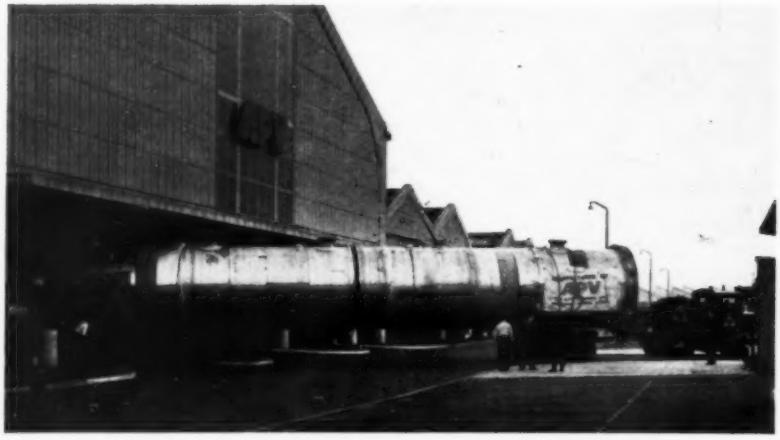
Head Wrightson Processes Ltd., the main contractors for the control panel for the high-flux Australian research reactor at Lucas Heights, near Sydney, ordered from George Kent Ltd. the actual control panel and all the physical instruments. Recorders for the nuclear instrumentation were ordered direct from Kent by Ekco Electronics Ltd.

Rhodes, Brydon & Youatt Ltd. have received an order from Boving & Co. Ltd., London, for the supply of seven vertical motor-driven drainage pumps for installation in the power station in Kariba Gorge. The Kariba project is reported to be one of the largest hydro-electric schemes in the world.

The contract for the heating and cooling system of the new synthetic-resin plant at Styrene Co-Polymers Ltd. has been awarded to Hygrotherm Engineering Ltd.

Simon-Carves Ltd. have received from Australian Iron & Steel (subsidiary of the Broken Hill Proprietary Co Ltd.) an important contract for a complete new coke-oven battery and by-product plant at the Port Kembla steelworks. The battery, it is believed, will be the largest in Australia and it will also be the first coke-oven installation of British design to be built in Australia by a United Kingdom firm.

A drive to expand production by 50% in three years, the opening up of new export markets, large reductions in prices and a five-year warranty on all commercial compressor units are the main items in a "Five-point Development Programme for Commercial Refrigeration" launched recently by Frigidaire. The programme, designed to take advantage of the rapidly-expanding markets for commercial refrigeration in the British Isles and overseas, was announced recently by Mr. A. W. Porter, general manager of the Frigidaire Division of General Motors Ltd. To help Frigidaire in Britain to get into the new export markets, a full-scale convention will be held in the Scala Theatre, London, on January 30, 1958.



The aluminium extraction column shown in our illustration is 80 ft long by 9 ft in diameter, and is reported to be one of the longest objects ever to travel by road, the overall length of the vehicle and column being 104 ft. The column is one of six being made by APV for Laporte Chemicals Ltd. for the production of hydrogen peroxide. Fabrication involved welding of aluminium 1¼ in thick.

It has been jointly announced by John Laing & Son Ltd. and the H. K. Ferguson Co. of Great Britain Ltd. that the two companies are forming a separate association in the name of Laing-Ferguson to provide a complete and comprehensive construction service to the chemical, processing and manufacturing industries.

Pencol Pipeline Engineering Consultants, 19 Grosvenor Place, London, S.W.1, has been formed by a group of engineers as independent consultants in the design of pipelines, pumping stations and ancillary equipment. The consultancy is a partnership of the following engineers: K. A. Spencer, J. de Waele, R. W. Stephenson, A. E. Crisp, P. W. Heselgrave and P. A. Tracy. Associated with them are N. Tetlow and R. G. Lamb.

The Kanigen plating process now being operated on production scale in this country by Albright & Wilson (Mfg.) Ltd., who are also the sole licensees for the new process in the U.K., Eire and Denmark, has recently been given the Ministry of Supply Reference No. DTD/900/4505. The Ministry has, at the same time, indicated its approval of the application of Kanigen to certain carbon and low-alloy steels, stainless steels and aluminum. Similar approval has been given by the Air Registration Board—Reference No. AI/5112/57.

Fielden Electronics Ltd. announced that a major holding in the company has been purchased by Hopkinsons Ltd. of Huddersfield, the well-known manufacturers of boiler fittings and controls. Mr. J E. Fielden, the founder of the company, still retains a substantial shareholding in the company and will continue to guide its future as chairman and managing director.

Gemec Chemicals Co. has moved to 103 Mount Street, London, W.1, telephone LEGation 5361. From June 1, 1957, the company is to be known as Union Carbide Ltd., Chemicals Division.

Weatherfoil Ltd., of Slough, Bucks, has established an air treatment division which will work closely with its existing heating and industrial divisions. A new office building is in the course of construction to house the unified project and will be ready for occupation in early September.

Blackman Export Co. Ltd., a subsidiary of Keith Blackman Ltd., has moved from 23 Queen Square, London, W.C.1, to the parent company's head office at Mill Mead Road, London, N.17. Keith Blackman Ltd. has opened a London area sales office at the Queen Square address.

Manesty Machines Ltd. has appointed The Fitzpatco Corporation, 1001 Washington Boulevard, Chicago, 7, Illinois, as its agents for the United States.

The following corrections to his articles on "The Tedman Separator" have been communicated to us by the author. They are as follows: May issue, p. 247, column 2, paragraph 4, second sentence—"This type of screen will often blind screens with the large amount of near mesh sizes present." This should read: "This type of *feed* will often blind screens . . ." June issue, p. 323, column 2, paragraph 1, second sentence—"The approximate particle-velocity through the boundary current will then be given by Stokes Law with v_t substituted for g." This should read: "The approximate particle velocity through the boundary current will then be given by Stokes Law *with the component of centrifugal acceleration* substituted for g."

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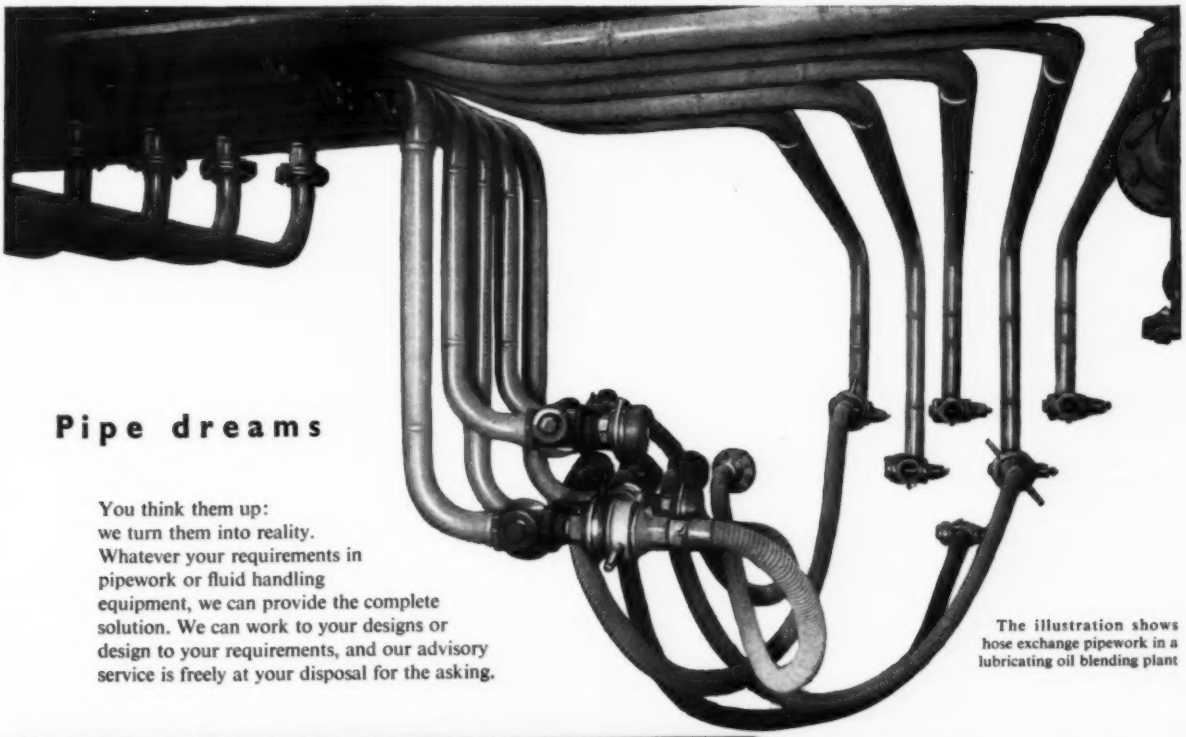

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People in the News

The Ministry of Education announces that **Sir Harold West** is resigning his appointment as chairman of the governing body of Loughborough College of Technology at the end of the present college academic year, having served in that capacity since the College became a separate entity in 1952. **Sir Edward Herbert**, of West Leake Manor, near Loughborough, has accepted the Minister's invitation to become chairman as from September 1, 1957. Sir Edward Herbert, who was trained as an engineer, is a director of a number of industrial undertakings in the engineering, textile and other fields; he is also a director of the Midland Bank and of the Northern Assurance Co. He is a member of the East Midland Division of the National Coal Board, of the East Midland Gas Board, of the North Midland Regional Board for Industry and of the Court of Nottingham University.

Q.V.F. Ltd. announces that managing director **B. H. Turpin** left England (on June 17) on a transatlantic tour to visit distributors and study the overseas market. Mr. Turpin will visit New York, Rochester and Detroit, after which he will make an extensive tour of Canada. **Mr. J. G. Window**, the firm's sales director, also left by air (June 22) to visit customers and agents in Norway, Sweden, Finland, Denmark, Holland, Italy and France.

The Lord President of the Council has appointed **Sir Harold Roxbee Cox** and **Dr. C. J. Smithells** to be members of the Council for Scientific and Industrial Research. Sir Harold Roxbee Cox is a director of Wilmot Breeden (Holdings) Ltd. and of The Brush Group Ltd. Dr. Smithells is managing director of Magnesium Elektron Ltd. and a former director of research to the British Aluminium Co. Ltd.

Under the statute of the Royal Society which provides for the election of persons who either have rendered conspicuous service to the cause of science or are such that their election would be of signal benefit to the Society, **The Marquess of Salisbury** and **Sir William Slater** have been elected Fellows of the Society.

Two appointments are announced by Shaw-Petrie Ltd./Clyde Tube Forgings Ltd. **John Montgomery** joins the board of Shaw-Petrie Ltd. and **Mr. Wallace Fairweather** is appointed general sales manager of Clyde Tube Forgings Ltd. and Shaw-Petrie Ltd. Mr. Fairweather is at the company's London office.

Sir George Briggs has been appointed a director of General Refractories Ltd., Sheffield. Sir George, who is on the board of The Brush Group Ltd., Payne Products International Ltd., Thomas Tilling Ltd and the Royal Ordnance Factories, is also a council member of the British Institute of Management.

The following have resigned from the board of The Brush Group Ltd.: **Sir Ronald W. Matthews, Rt. Hon. Lord Cunliffe, Capt. R. C. Petter, Major Noel E. Webster and Mr. Miles Beevor.** The following have been appointed to the board: **Sir Frank Spriggs, Sir Roy Dobson, John F. Robertson and Sir Arnold Hall.**

At a recent meeting of the board of directors **Mr. W. Morgan Thompson** was appointed a director of Monsanto Chemicals Ltd. Mr. Thompson had previously been an alternate director since July, 1956.

Mr. F. Davenport, assistant to **Mr. Harry Willshaw**, chief engineer of the Dunlop Rubber Co., has been appointed deputy chief engineer at the company's head office in London.

Babcock & Wilcox Ltd announced the appointment to its board of directors, on June 11, of **Mr. Iain Maxwell Stewart** and the **Rt. Hon. Lord Bridges.**

Mr. Barrell, generation engineer (construction) in the Yorkshire Division of the Central Electricity Authority, has been appointed generation construction engineer, C.E.A. Headquarters.

British Oxygen Chemicals Ltd. announces the appointment of **Mr. A. J. Oxley** as production manager at its works at Chester-le-Street.

The Corday-Morgan Commonwealth Fellowship for the academic year 1957/58 has been awarded to **Dr. E. A. Magnusson**, Teaching Fellow in the School of Applied Chemistry at the New South Wales University of Technology, Australia. During his fellowship, Dr. Magnusson will work under the supervision of **Professor D. P. Craig**, in **Professor C. K. Ingold's** Department at University College, London. The Corday-Morgan Commonwealth Fellowship is tenable for one year only in some part of the British Commonwealth other than that in which the candidate received his scientific education. The award is made by the Corday-Morgan Memorial Fund Executive, consisting of the presidents and immediate past presidents of the Chemical Society, The Royal Institute of Chemistry and the S.C.I.

Mr. Arvon L. Davies, managing director of Chemstrand Ltd., has announced the appointment of **Chester H. Goodwin** as project manager for Chemstrand's new Acrilan acrylic fibre plant now being constructed at Coleraine, Northern Ireland.

Mr. H. A. Luss has been appointed chairman of the Nuclear Group of the Scientific Instrument Makers' Association. Mr. Luss, who is at present joint managing director of Isotope Developments Ltd., has also been appointed deputy chairman of that company.

Col. D. G. N. Lloyd-Lowles is the new chairman of the Amber Group of companies, of which has has been a director for some time. He succeeds the late **Mr. Arthur Mortimer,** who died in January of this year. Col. Lloyd-Lowles is also a director of Electric & General Industrial Trusts Ltd. and of Firth Cleveland Ltd., and is chairman of The Tap & Die Corporation Ltd. **Mr. G. C. Baker** (the group secretary) has been appointed to the board of Amber Chemical Industries Ltd.

BIRTHDAY HONOURS LIST

F. Pickworth.

E. W Thompson.

J. Bowman.

C. M. Vignoles.

The Queen's Birthday honours list included the following:

Knights Bachelor: **F. Pickworth**, chairman, English Steel Corporation; **E. W. Thompson**, chairman, John Thompson Ltd., Wolverhampton; **A. T. S. Zealley**, chairman, Remploy Ltd., and formerly a group director of I.C.I.

Order of the British Empire, K.B.E.: **J. Bowman**, chairman, National Coal Board. *C.B.E.:* **J. L. M. Morrison**, professor of mechanical engineering, University of Bristol; **J. G. Pearce**, director of research, British Cast Iron Research Association; **S. Smith**, chairman, Scottish Gas Board; **D. G. Sopwith**, director of mechanical engineering research, D.S.I.R.; **C. M. Vignoles**, managing director, Shell-Mex & B.P.; **J. Wright**, director, Dunlop Rubber Co. *O.B.E.:* **R. S. Haskew**, chairman and managing director, General Chemical & Pharmaceutical Co.; **G. Weston**, technical director, British Standards Institution; **E. Whitworth**, deputy research manager, I.C.I. (Nobel Division), Ardeer. *M.B.E.:* **E. H. Coleman**, senior experimental officer, Fire Research Station, D.S.I.R.; **H. Lloyd**, chief experimental officer, metallurgy division, A.E.R.E., Harwell; **T. H. Messenger**, head of library and intelligence division, Research Association of British Rubber Manufacturers; **H. W. Newill**, personal assistant to joint managing director, Blaw Knox.

Lord Bridges.

I. Maxwell Stewart.

BCE 1637 for further information

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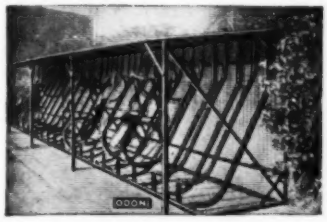

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BCE 1638 for further information

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